THE SHEEP AND ITS SKIN

ALFRED SEYMOUR-JONES

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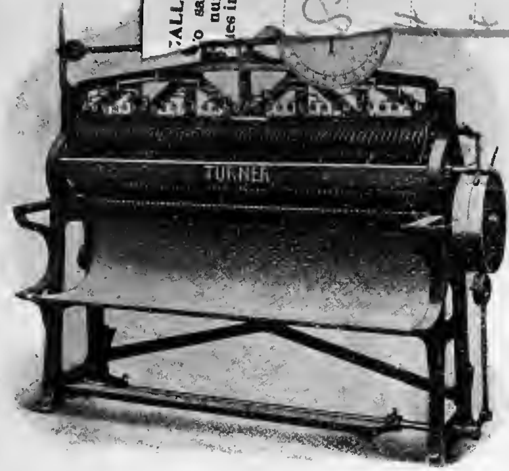

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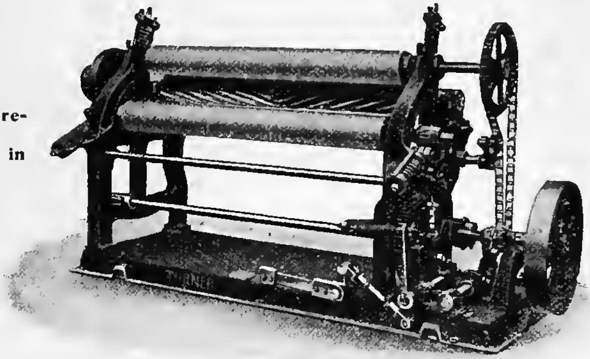

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THE SHEEP AND ITS SKIN

" Oh yes, believe me, you must draw your pen
Not once or twice, but o'er and o'er again,
Through what you've written, if you would entice
The man who reads you once to read you twice,
Not making popular applause your cue,
But looking to find audience fit though few."

HORACE.

BIG HORN (*Ovis canadensis*). [*Frontispiece.*

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THE SHEEP AND ITS SKIN

A TEXT-BOOK OF THE HISTORY, BREEDS, FEEDING, DISEASES, AND AFFLICTIONS OF THE SHEEP;
AND OF THE
PELT AND WOOL CONSERVATION, FELLMONGERING AND WET-WORK TREATMENT OF THE PELT PRIOR TO TANNING

BY

ALFRED SEYMOUR-JONES

EX-PRESIDENT OF THE INTERNATIONAL ASSOCIATION OF LEATHER TRADES CHEMISTS
CONSULTANT EXAMINER TO THE LONDON CITY AND GUILDS ON SKINS AND SKIN DRESSING; CHAIRMAN OF THE INTERNATIONAL COMMISSION ON THE PRESERVATION, CURE, AND DISINFECTION OF HIDES AND SKINS, ETC., ETC.

WITH NUMEROUS ILLUSTRATIONS

LONDON
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1913

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AND ALLIED INDUSTRIES

CONTENTS

CHAPTER		PAGES
I.	INTRODUCTION	1–19
II.	HISTORICAL ACCOUNT OF THE EVOLUTION OF THE SHEEP	20–48
III.	BREEDS OF SHEEP, CROSS-BREEDING AND FATTENING	49–95
IV.	MASTICATION, DIGESTION, AND BLOOD CIRCULATION	96–123
V.	DISEASES OR AFFLICTIONS OF THE SKINS OF SHEEP	124–155
VI.	FLUKE OR LIVER-ROT IN SHEEP. BY PROF. A. P. THOMAS	156–203
VII.	"COCKLE" IN SHEEPSKINS	204–221
VIII.	THE PRINCIPLES OF MODERN FELLMONGERING	222–286
IX.	THE TREATMENT OF SHEEP PELTS FROM THE FELLMONGERY TO THE TANNERY . . .	287–356
	APPENDIX — BACTERIOLOGY IN THE LEATHER INDUSTRY. BY J. T. WOOD . .	357–386
	BIBLIOGRAPHY . .	387–390
	INDEX . .	391–396

LIST OF ILLUSTRATIONS

PLATES

NO. PAGE

Big Horn (*Ovis canadensis*) . . . . *Frontispiece*

2. Welsh Mountain Ram 3
3. Black-faced Mountain Ram 9
4. Shropshire 2-Shear Ram 15
5. Cheviot Ram 23
6. Kent or Romsey Marsh Ram 31
7. Dorset Horn Ram 37
8. Border Leicester Stirling Ram 45
9. Herdwick Ram 67
10. Bye products 73
11. A small Fat-lobule from the Subcutaneous Tissue of the Guinea-pig, magnified about 20 diameters (E.A.S.) 81
12. A few Cells from the margin of the Fat-lobule represented in the preceding figure; highly magnified (E.A.S.) 81
13. A highly magnified Horizontal Section of Human Skin cut through the fatty layer, and stained by Dr. Drinkwater, of Wrexham . 85
14. A Section cut from a Sheepskin showing "colt" 91
15. A Section of "colt" more highly magnified 91
16. Another Section of same 93
17. The Stomachs of the Sheep 101
18. A Photo-micrograph of an Injected Section of Human Skin . . . 107
19. A more highly magnified Photo of part of same 107
20. A highly magnified Photo of Section of Human Skin 113
21. A very highly magnified Photo of Human Skin 113
22. Enlarged Photo of Sheep Skin after tanning 119
23. Similarly prepared section 119
24. A direct Photo of Flank off a Sheepskin after Chrome Tanning . . 121
25. A Section of Human Skin, showing a hair *in situ* 131
26. A more highly magnified photo of same section 131
27. Two Vertical Ribbon Sections cut through 2 Cockles 219
28. Two Sections Cockles, showing Black Spots in Fatty Layer . . . 219
29. A Dewooling Machine in operation with sorting table 235
30. Dewooling machine with sorting delivery table 237
31. Feed-end of Two-section Right-hand Wool Dryer 241
32. Doffer end of Two-section Right-hand Wool Dryer 243
33. Roller Fleshing Machine for Sheep Pelts 247
34. Photo of Pickled Skin from New Zealand, showing Fungoid Decay 255

NO. PAGE
35. Closer View of Pickled Skin from New Zealand, showing Fungoid Decay 257
36. The Red Muscle (*Panniculus carnosus*) 303
37. Pure Culture of a Bacillus 384
38. Section of sumac tanned Calf Skin 385

ILLUSTRATIONS IN TEXT

The Musk-Ox (*Ovibos moschatus*) 50
The Siberian Argali Sheep (*Ovis ammon*) 53
Head of the Siberian Argali Sheep (*Ovis ammon*) 54
Head of "Unicorn" Burwal Ram 56
Africander Fat-tailed Ram 58
Half-bred Abyssinian Maned Ram 59
Wallachian Ram 61
Four-horned Piebald Ram 62
Four-horned Manx Loaghtan Ram 63
Sheep-Scab Mites (*Psoroptes communis*) 138
Sheep Ked (*Melophagus ovinus*), and Puparium of Ked 145
Sheep Tick (*Ixodes reduvius*), young state, and Sheep Ticks (*Hæmaphysalis punctata*), distended 146
The Sheep Maggot Fly (*Lucilia sericata*), Pupa Case, and Maggot . . 150
Egg of the Liver-fluke 165
Egg of the Fluke, containing an Embryo 168
Embryo of Fluke as it appears when swimming 168
Embryo of Liver-fluke boring into a Snail. 170
Change of Embryo into Sporocyst 173
Young Sporocyst and Full-grown Sporocyst 174
Young Redia and Full-grown Redia 176
A Cercaria 178
A Cercaria in the Act of forming its Cyst or Envelope 179
Three Cysts of the Liver-fluke attached to a Portion of Grass-stalk . . 179
Three Young Flukes from the Liver of a Sheep 185
An Adult Fluke, showing the Branched Digestive Tract 186
Another View of an Adult Fluke, showing the Reproductive Organs . . 186
The Snail (*Limnæus truncatulus*), which serves as Host to the Sporocyst, Redia, and growing Cercaria of the Liver-fluke 198
Limnæus truncatulus, of natural size 198
A Wringing Machine for Woolskins 232
Straiton Burring Machine 271
A Washing and Wringing Machine for Woolskins 277
Bacillus Putrificus (Bienstock) 383
Lime Speck on a Sheep Skin 383

THE SHEEP AND ITS SKIN

CHAPTER I

INTRODUCTION

> "I search and search, and where I find I lay
> The wisdom up against a rainy day."—HORACE.

IN the ensuing chapters of this volume it is the author's intention to treat of matters, hitherto neglected, but nevertheless of great importance for the successful production of sheepskin leathers. It would be unreasonable to assume that the information given represents any complete or final dictum on this all-important question, as the main object of the book is to provide a ground matrix in the literature of the subject to stimulate trained and well-equipped observers to devote some of their energies to the elucidation of the most interesting problems presented by the sheep and its skin.

The astounding poverty of technical literature on the general physiology of the skins of animals must always be a matter for adverse comment, and arises doubtless from the fear of disclosing "trade secrets," or from a mistaken belief that there is no demand for such knowledge. In the fierce competition of the present day our technical men are generally anxious to assimilate all the information possible with regard to their craft, whether derived from personal instruction, practical experience, or solid reading, and it is to provide in some small measure for the last demand that the author has been tempted to write the present book. It is hoped therefore, that many workers and observers will be induced to record the results of their labours, for it is only by the united industry of many labourers that the solution of the all too numerous difficulties of this and other problems can be arrived at.

No work dealing with the skin of the sheep would be complete without some historical references. The chapter giving a historical account of the evolution of the sheep is not complete, but sufficient to show that the progenitors of the modern breeds have a more remote antiquity than is generally known, that as an item in the economy of man's life the sheep has played an all-important part practically from the advent of man some millions of years ago, and that the modern breeds have arrived at their present condition by the natural process of evolution. Prior to the dawn of history, the unique position of the British Isles lent itself to the specialising in breeds of sheep, a position which time has not effaced but improved, with the result that the world draws upon these islands for sheep whose purity of breed is guaranteed, and from which the oversea breeds may be strengthened or improved.

The leather industry takes rank among the first six great industries of the world. In this industry, the sheep skin, as it falls from the carcase, yields a larger

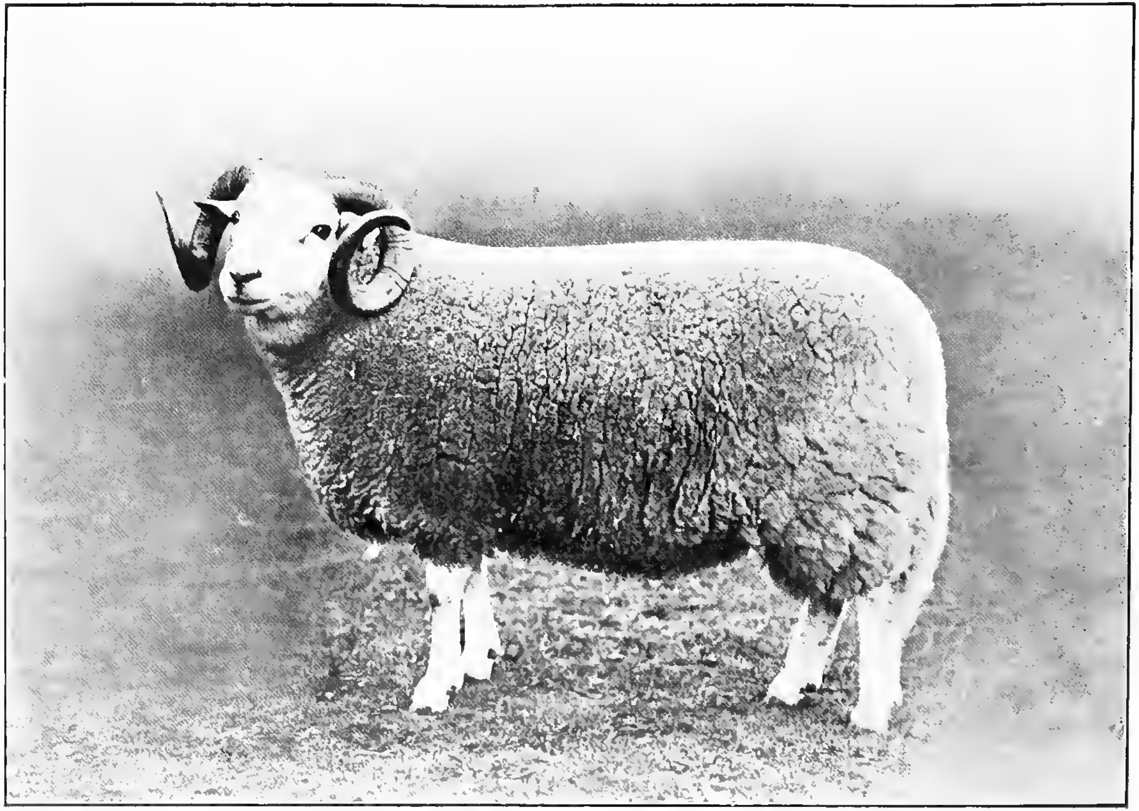

Plate 2.

Welsh Mountain Ram.

source of wealth than is obtained from the skins of any other animal. Numerically, the supply of sheep skins exceeds that of all other skins which enter into the art of making leather.

It is estimated that there are more than six hundred millions of sheep in the various countries of the world. Of this vast total four hundred and fifty millions are in those countries making returns. From reliable data, which I have obtained over a number of years, it would appear that from one-third to two-fifths of the total sheep are slaughtered every year. This estimate has been questioned on several occasions. The country which yields us the most precise figures is New Zealand. If any one will take the trouble to ascertain the number of carcases of sheep and lambs shipped from New Zealand annually, add to this a sufficient number to supply the wants of the New Zealanders, and then divide this total into the total head of sheep, he will find that my estimate is fairly accurate. On the hypothesis that the yield of sheep and lamb skins is at least one-third of the total head of sheep, the British Islands will supply from ten to twelve millions of skins annually from her own sheep. Other countries may not supply or place on the markets all the skins which may be flayed from sheep. In many cases it will not pay to export skins, but rather to take off the fleece and destroy the skin. Hence, while the world is capable, under this rule, of supplying about two hundred millions of sheep skins annually, it would be manifestly unfair to assume that anything like this quantity are available or offered for sale. The fact remains that sheep are grown for their wool and not for their skins; many of the latter are lost through lack of cheap transportation, and can only be considered as so much offal. With the constantly increasing means of rapid transit, this loss will in time remedy itself.

Although Great Britain is the head quarters for the supply of pure breeds, be they sheep, ox, horse, hog, etc., there are breeds in other lands possessing distinctive qualities in wool and pelt; only one need be mentioned, viz. the Spanish merino, which has found a happy home in Australia, where it flourishes more than it does in its original habitat.

Sheep, considered as a whole, form one of nature's greatest assets. It yields a wealth of valuable materials, which find their way into the various channels of commerce. Primarily grown on account of its wool, which now totals to an astounding weight and value annually, the carcase has been developed for food by increasing its weight and bulk. Of such carcases the oversea dominions, the Argentine, etc., ship many millions every year to Europe. The amount of fat produced by the sheep is becoming one of the most valuable portions of the total trade, on account of the increasing demand and values of such fats in the arts, like that of soap making, etc. This feature requires to be watched carefully by the sheepskin tanner, because, as the value of all fats rises, it is quite probable that sheep may be grown and fed in greater bulk than is accomplished even to-day with the special view of fat production in preference to the increase of its flesh. If this should happen, as is quite probable, the quality of the pelt will decrease seriously, and the difficulties of producing sound leather will follow. The capacity of the sheep to assimilate food is dealt with in Chapter IV., under "Mastication, Digestion, and Blood Circulation." Though brief, the chapter is sufficient to show the enormous powers of digestion and rapid bulking of its carcase under given conditions.[1] In an article published some time ago, attention was directed to the effect of artificial feeding of animals and its effect upon the pelt. It is not necessary to repeat the observations made therein as they have been fully admitted, but the importance of the trade continuing to study the silent changes which are steadily, even stealthily, being pursued by stock raisers throughout the world, in effecting so-called improvements in the character of their flocks or herds, must be persistently followed up and noted, in order that the processes of manufacture may be adjusted and amended accordingly.

Numerically the position of the sheep to-day is unsatisfactory.[2] In all European countries the total head of sheep is steadily declining. In Germany, France, Austria, and Belgium the decline is very serious; in the last country enumeration is no longer worth while, for the quantity is too small. In Great Britain the decline is not so serious, but nevertheless it is steady, and shows no tendency to permanent increase. Taking the twenty-two European countries making returns (including European Russia and

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[1] "Observations on the effect of 'Artificial Feedstuffs' upon Hides and Skins." The Author.

[2] "The World's Hide and Skin Supply." The Author.

Asiatic Russia), in 1880 the total head of sheep amounted to 213 millions, in 1907–8 it had declined to 184·4 millions, while the population during the corresponding period had increased from 338·8 to 447·8 millions. Taking the figures for those countries throughout the world making returns, 452·1 millions of sheep were enumerated in 1880, and 451·9 millions in 1907–8. Against this the population over the same period has increased from 411·1 millions to 572·7 millions, while individual wealth and purchasing power have increased enormously. It is true that drought in certain countries during certain years will seriously affect the enumeration, causing a fluctuation of possibly 50 millions, but even then they show no tendency to increase *pro rata* with wealth and population. The fact is that, in industrial countries, sheep do not produce so much wealth from the same area of land as the industrial buildings erected thereon. In some countries formerly noted for sheep products, the land is being ploughed up to grow wheat and other cereals to the displacement of both cattle and sheep. In those countries cattle no longer roam over the lands, but are in the main stall fed, while the sheep are either driven off to new lands or are killed and not replaced elsewhere. Viewing the whole question of supply and demand, the outlook is not encouraging, therefore it behoves the manufacturer thoroughly to study the entire situation.

In spite of the decrease of numbers the total weight of carcase and wool has been increased in nearly all breeds of sheep, especially in the sheep resulting from a

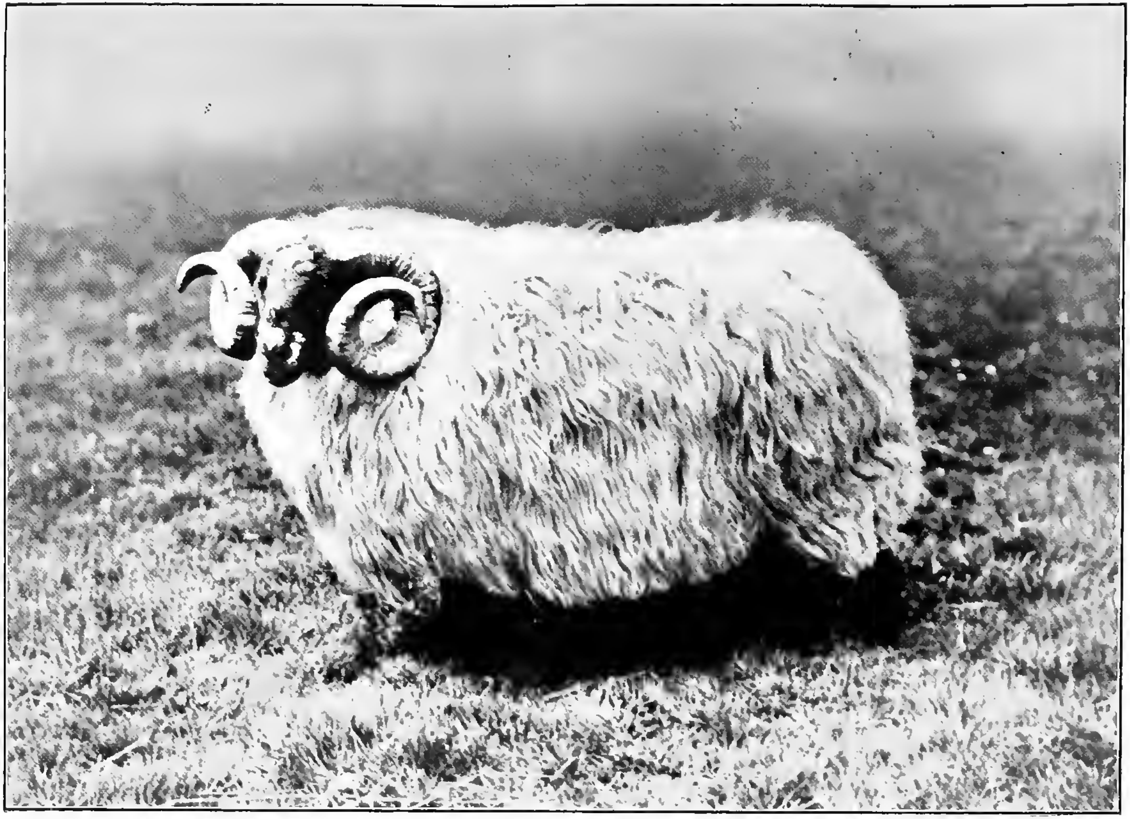

Plate 3.

study of cross-breeding conditions, and artificial feeding. In a measure this implies that a larger pelt should be the result, which, in a limited sense, is true; but the quality would appear to have suffered from the operations. This phase of the subject is dealt with in Chapter III.

There are lands, like India, which produce a sheep which is not far removed in breed from that of the ancient Argali or parent sheep. The Indian sheep are not grouped with those of the wool-bearing varieties but with the hairy class, although wool of sorts may be present. The pelts off such sheep produce the skins known as East Indian tanned, both of goat and sheep, which are offered for sale in large quantities every six weeks at the Mincing Lane sales in London. The Government of India is naturally desirous of improving the wool-bearing qualities of such sheep, in order to increase the wealth of that empire. To this end, certain breeds of wool sheep, including Australian merino, have been imported, and the rams crossed with native stock. There is no reason why the experiment should not succeed, provided the strain produced can be acclimatised. Should the experiments prove successful, then the purity of the native strain will tend to disappear, and the pelts will not carry those features so much sought after to-day, and which has made them famous.

In other countries, following out recognised principles of cross breeding, the native shepherds have succeeded in altering the character of the sheep by crossing with the native goat. This cross has been practised from time immemorial, so that the division line between sheep and goat is very obscure; in fact, it is difficult in some breeds to differentiate clearly between a sheep and a goat. Formerly this crossing was rather an accident than a design, but with the enormously increased demand for goat skins, advantage has been taken by breeders to produce a cross-bred sheep by crossing it with a goat and thus secure a pelt which in some characteristics favours that of a goat skin, possessing a smaller amount of skin fat.[1]

The subject of so-called "skin diseases" or affections of the skins, a complicated subject, is fairly completely dealt with from the tanner's standpoint. It includes such injuries, inflicted by mankind, as tar-branding, etc. This is a big question and one of wider interest than that of the leather trade alone.

On July 29, 1909, the Leathersellers Company of London took the initiative in calling to a round-table conference all the trades' representatives who were interested in the diseases or injuries affecting skins of those domestic animals which enter into the making of leather.[2] The representatives at that meeting were unanimously of the opinion that improvements could be effected in time by carefully watching the course of events and helping the recognised authorities. The task is a gigantic one, and for the purpose of carrying out these observations, a committee was formed, called the Allied Trades Committee, who have held meetings and done effective work, but such a committee can only be thoroughly efficient provided it continues its meetings, deliberations, and representations. Similar committees have been formed on the Continent.

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[1] In some quarters doubt has been expressed in regard to this "cross." See "Sheep and its Cousins," by Lydekker.

[2] A full report of this meeting appeared in many of the trade journals. See *Leather Trades Review*, August 4, 1909.

Chapter VII., on "Cockle," may possibly solve this mystery once and for all. The solution has not been hastily arrived at; on the contrary, over thirty years of close observation and research have been devoted to its present solution; it is hoped that the work has not been in vain and that it will interest the tanner.

The chapter on "The Principles of Fellmongering" does not profess to deal so much with the operations in complete detail as with laying down the general line of action, with some explanation as to their cause and effect. In Great Britain, as in some other countries, the trade of a fellmonger is included under that of "offensive trades" as interpreted by Act of Parliament. In most cases the inclusion would seem to be warranted, especially in the older type of fellmongery, where it has not been realised that the handling of matter subject to putrefaction creates an offence, not only to those living in the immediate vicinity, but to those residing in more remote parts and, indirectly, to the fellmonger's more up-to-date colleagues.

Fellmongering under the most approved conditions, although involving the handling of skins which may have been in contact with disease or which may attract disease-carrying flies, is a trade which should and can be hygienically performed. To accomplish this ideal, the works should be kept systematically clean, and no pieces of decaying skin or pelt should be permitted to remain exposed to the attack of flies for a longer period than is absolutely necessary. Every precaution should be taken to wage a war of extermination on all flies. No old or stale lime liquors should be in evidence. The yard broom should be brought into constant operation, and the atmosphere should be improved by utilising one of the many deodorants on the market.

In view of the altered conditions brought about by cross-breeding and artificial feeding, it is of supreme importance to the sheepskin tanner that some alteration should be made in the system of modern fellmongering, especially in Great Britain, in regard to the conservation of the dewooled pelt. Suggestions for such alterations are made in the final chapter, and although they may strike many as revolutionary and visionary, nevertheless they are in extensive operation to-day over greater areas and on much larger quantities of pelts than are fellmongered within these Isles. It is hoped that these suggestions will bear fruit.

The final chapter illustrates and indicates lines on which the operations performed during the various stages of the beam house or wet work may be equally and successfully carried out by the aid of physico-chemical reactions, as opposed to the prevailing opinion that such operations can only be successfully performed by the aid of bacterial action. It will no doubt contain much which is novel to many readers, but the main object is to call attention to the lines of future development and research. All the processes, as described, have been carried out, and are being carried out, upon

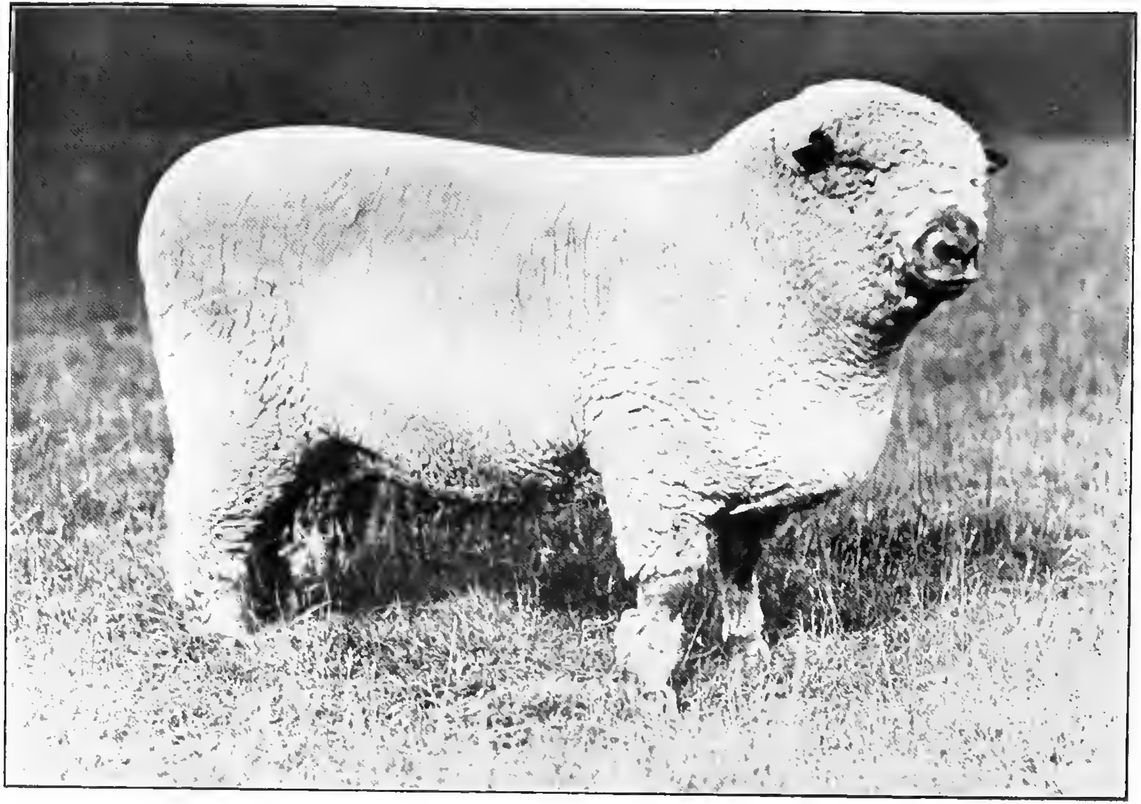

Plate 4.
Shropshire 2-Shear Ram.

all classes of hides and skins, in many factories producing the highest possible grades of stock. My hope and sincere wish is that the contents of this chapter, though somewhat brief, will lead others to study the effects of physico-chemical mass action in the wet work, and so once and for all eliminate that disgusting material, dogs' dung or excrement of any animal, from the industry, and, in this respect at least, cast out the slur upon the leather industry of being classed by various governments as an "offensive trade."

It is not intended that this volume should assume the dignity of a scientific treatise of the subject, although it may reasonably claim some merit in that direction; but, so far as it is within my power, I have endeavoured to write so as to be understood by the average working-man who is desirous of seeking knowledge in his craft. With the altered conditions of modern employment, the abolition of the old apprenticeship principle and the introduction of the present-day alternative, the technical school and local technical classes, the compulsory education of all grades in the primary schools, with the increase of free public libraries, the strain of competition becomes increasingly severe, and it is absolutely imperative that literature of a sound technical character should be forthcoming at a moderate price within the means of every working-man, in order that he may so far educate himself as to make his services of far greater value. Such an education can be gained by attending a technical school, but unfortunately the supply of such technical establishments is, as a rule, almost confined to the larger towns;

but much good can be done by traders grouping their forces and energies in given areas and engaging good expert teachers to give lectures and demonstrations, or a course of evening classes in instruction in the principles of the local industries. Such instruction should comprise technical and commercial education. The employers will find it to their pecuniary advantage to encourage the attendance of their workmen, especially the younger generation, at the classes, and to offer them rewards according to the results of their application of the principles inculcated to everyday work. Most employers appreciate the workman who displays the ability of doing the right thing at the right moment. Such workmen aid substantially in building up big industries, and should be promoted and rewarded, and given every opportunity to improve their minds. Human nature is full of the milk of human kindness, and such men will usually be of use to their employers in exact proportion to the employers' appreciation of their services.

Meanwhile, pending the fulfilment of some scheme of educational facilities, these men must rely upon technical works for self-improvement in those districts remote from technical schools. It is with the hope of its being of real educational value that this book is launched.

In compiling such a book as this, I have, as might naturally be expected, drawn from many sources for the information contained herein. It is not possible to acknowledge all the many authorities, as some of them are so modest as to hide their identity under a *nom-de-plume*, but so far as I have been able, acknowledgment of the source has been made in a footnote.

I am especially indebted to my friend Prof. H. R. Procter for much kind advice and analysis of cockle-wool fat, and to Mr. R. A. Seymour-Jones for his kind assistance in the analysis of the cockle fats and the mutation of skin fats, an admittedly difficult subject into which much research has yet to be made.

Sir Stewart Stockman, the chief veterinary officer of the Board of Agriculture, has rendered much good advice and help in handling those subjects upon which he is a recognised authority.

To the Director of the Natural History Museum, South Kensington, London, I desire to tender my best thanks for his kind permission to reproduce some of the illustrations of the many interesting sheep exhibited at that museum. It is to be hoped the student will avail himself of the opportunity offered by such a collection to become familiarly acquainted with the animals whose skins he may have to operate upon within the factory.

The disease known as "fluke" or "liver-rot" is much misunderstood by leathermen and shepherds alike. The first part of the chapter on this disease is from my pen, and the balance is by Prof. Thomas, who, having made a special study of the disease and elucidated the life-history or cycle of the fluke, wrote a monograph for the Royal Agricultural Society of England, to whom I acknowledge my grateful indebtedness for their kind permission to republish the whole of Prof. Thomas's paper, and the loan of the blocks for illustration.

CHAPTER II

HISTORICAL ACCOUNT OF THE EVOLUTION OF THE SHEEP

"History is philosophy learned from examples."—THUCYDIDES.

THE two sciences, Geology and Anthropology, enable us to fix with reasonable accuracy the period of time in the history of the world when the progenitors of the modern sheep made their first appearance on this globe. The story of evolution is an absorbingly interesting one, and although it forms no part of our programme to deal with that wonderful story, it may not be out of place to draw attention to certain facts not generally known to the average reader of leather trade literature.

Without relating the whole of the nebular hypothesis of the earth's creation, the geological table given herewith unfolds at a glance the story of Evolution as it has been worked out by the students of the above twin sciences. This table represents the relative position of the various strata of the earth, and it should be noted that, for chronological purposes, the table should be read from bottom upwards.[1]

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[1] The author is indebted to Mr. Joseph McCabe for his kind permission to quote from his excellent popular books, entitled "Prehistoric Man," and "Evolution," in the Twentieth Century Science Series; and to reprint his Geological Chart.

A SIMPLE GEOLOGICAL SCALE.

Epoch.	Period.	Relative Age.	Types of animal life that appear.
Quaternary (actual)	Holocene Pleistocene	years 500,000	Neolithic and modern man. Paleolithic man.
Tertiary ...	Ploiocene Moiocene Oligocene Eocene	5,000,000	Ape-men of Java. Anthropoid apes, apes, horse, camel, hog, elephant, ox, sheep, rhinoceros, etc. Lemurs, early horse, whale, etc.
Secondary	Cretaceous	7,200,000	Toothed birds, bony fishes.
	Jurassic	3,600,000	Crab, higher insects. crocodile, flying reptiles, archæopteryx.
	Triassic	2,500,000	Monotremes and marsupials.
Primary ...	Permian Carboniferous	9,000,000	Reptiles. Amphibia.
	Devonian	8,000,000	Fishes—elasmobranchs, dipnoi, and ganoid.
	Silurian Ordovician	5,400,000 5,400,000	Insects, ostracederms, cephlopods.
	Cambrian	8,000,000	Rhizopods, sponges, corals, worms, crustacea, hydrozoa.
Archaean	Pre-Cambrian	Indefinite	

NOTE.—The above table is simplified for the purpose of this work. The age is assigned approximately (from the thickness of the strata) on a scale of fifty-five million years for the stratified rocks.

Although the sheep appear in the moiocene period in company with the ape, horse, camel, hog, elephant, ox, rhinoceros, etc., about 2,500,000 years ago, the period of interest to our purpose starts with the advent of Prehistoric man.[1] We have plenty of evidence in the Quarternary epoch that man had developed agriculture, and had, doubtless, previously domesticated first the docile sheep, and later the ox, using their products for his needs. The knowledge of the domestic life of Palaeolithic man, *i.e.* in the older stone age, is scanty, but the knowledge of his habits during the Neolithic, or New Stone, Age is more complete, and it is possible to speak with some degree of authority on such matters as are of interest.

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[1] Fossilised remains of Sheep and Goats may be seen in the Natural History Museum, South Kensington, in Galleries 1 and 2, Pier-case 16.

Early Neolithic man tamed the dog, developed agriculture and weaving, but had not yet tamed the sheep and the ox. During the later period of Neolithic man, the sheep, ox, horse, cat, and fowl, were domesticated, but only became common in the dawn of the Bronze Age. In some places the flocks seem to have been brought into the settlement from the fields at night, to protect them from wild animals. There are, apparently, traces of dressed hide or skin, or leather, as if some kind of foot covering was made.[1]

Antediluvian Sheep.—The Bible contains many references to the sheep, and no animal in the economy of nature produces such a wealth of material for the use of man as the sheep. This must have been recognised at a very early period. The sheep yields wool for clothing, skins for tents, milk, cheese, butter, meat, fat, etc. We find the earliest reference to the value of the sheep in the story of Cain and Abel, "Abel was a keeper of sheep," and in the next verse, "and Abel, he also brought the firstlings of his flock, and the fat thereof." One purpose for which these were kept is sufficiently plain; although the climate was genial, it was felt that

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[1] Remains of some sort of covering have been found on the feet in the graves of Neolithic man in Denmark, which indicate, that some of the leather had been employed for the purpose.

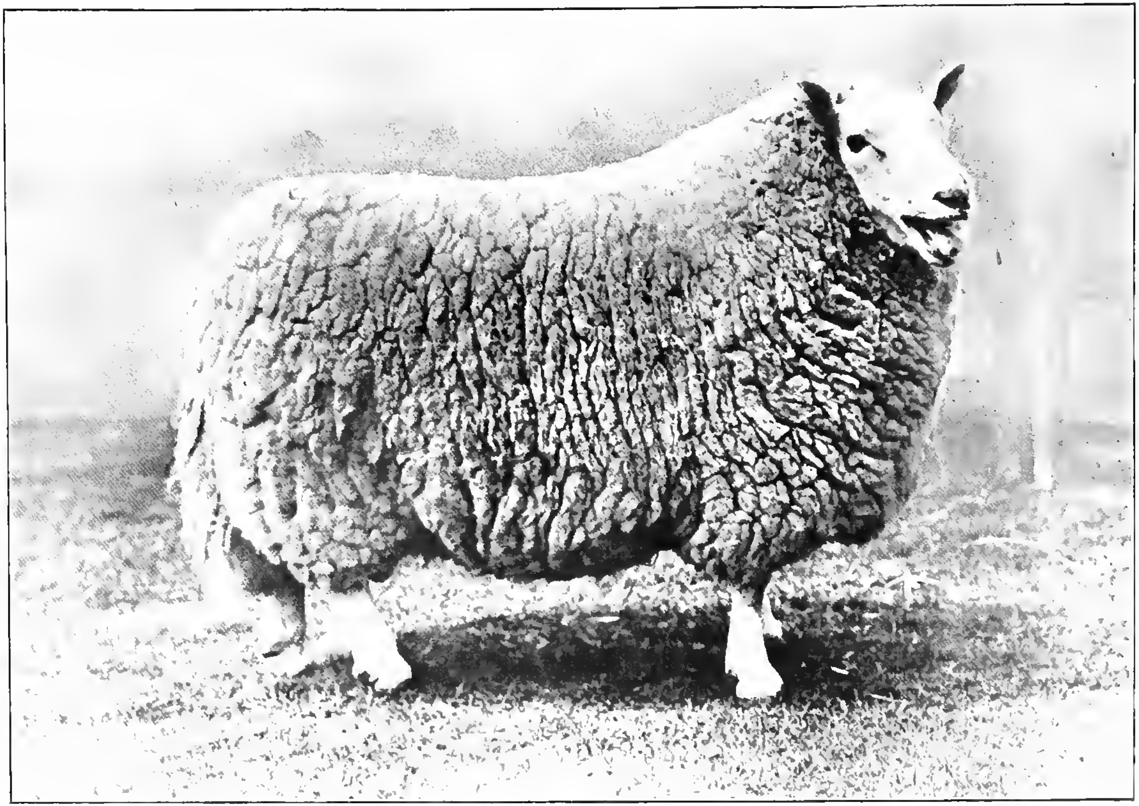

Plate 5.
Cheviot Ram.

instead of the fragile and insufficient covering of the primeval fig-leaf, a warmer and more comfortable costume was desirable and might be devised from the fleece-bearing skin of the sheep.

It is probable that the sheep was not then used for food, as ancient history is uniform in asserting that, in primeval times, the use of the flesh of the domesticated animal as a food was unknown. Probably the employment of sheep for food purposes was a development of the sacrificial rites.

A further mode in which the sheep has through every period of ancient history, in many countries, even to the present day, contributed to the support of man, viz. by the milk obtained from the female, is mentioned in many instances in the Scriptures. From the milk butter, cheese, etc., were made; the art of churning to make butter would seem to be of very remote date. Solomon, who collected the ancient proverbs of the East, refers in chap. xxx. 33, "Surely the churning of milk bringeth forth butter."

The dress of the first man and woman was precisely similar to that of the inhabitants of every country in the early period of civilisation, or before civilisation can be said to have commenced. The inhabitants of ancient Greece are described as clothed in the skins of animals which were either domesticated or killed in hunting. The ancient Britons, when their island was first visited by the Phœnicians, were either naked and their bodies fancifully painted or clad in the skins of animals.

To use the simple untreated skin as removed from the animal's back as clothing is quite out of the question. It therefore became necessary for the primeval hunter to devise some means of rendering it imputrescible. At first the skins merely underwent the process of drying, and were then fastened round the neck of the wearer by a simple thorn or strip of softened raw hide or skin; and they were worn with the wool within or without, according as the weather was cold or hot, dry or wet. By degrees they were fitted to and disposed on various parts of the body, and cut into form, or selected in various colours according to the fancy of the wearer. It is obvious that here there was room for the exercise of considerable ingenuity. Probably the observation of the effect of the natural fats in the skin as a softening agent led to the introduction of adding fat as a cure and softening agent; a method still pursued by the nomadic races of the East.

The early improvement in Sheep.—Passing over the admixture, in the process of time, of other skins of domestic or tame animals, and confining the inquiry to the sheep alone, the commencement of the improvement of that animal, although perhaps proceeding slowly, may be easily assumed and believed. Colour would be an object of some importance, and the skin being valued according to its purity or brightness, or fashion (for it must have been indeed an early period of the world when that power had not begun to exert its influence!) an attempt would be made to perpetuate a given colour in the flock. Individuals would be selected to breed from with an especial regard to this purpose, and the fundamental principles of breeding would be recognised and acted upon. The size of the skin would be a material object, and large sheep would be selected. The warmth of the clothing would become a more important affair, thick and close, or long and shaggy fleeces, would be sought after. The unpleasant sensation caused by the contact of coarse wool with the human skin would lead to the choice of that of a fine and soft kind. A principle of economy, a desire to make this rude coat last as long as possible, would produce attention to the food and to the diseases of the animal, for it would be perceived that appearance of the wool to the pelt was intimately connected with the health of the sheep. Many centuries would scarcely pass before the discovery of the art of dyeing, which would be naturally suggested to early man by the colour produced by fruit and wild berries staining his hands when gathering them. The application of such stains to wool would bring about the art of dyeing. The improvement of the sheep may therefore be considered as having commenced even in those remote times, and with this rude kind of clothing.

A further point of interest lies in the fact that the early nomadic shepherds, as is the case to-day, utilised the skins of the sheep to make their tents.

Sheep flesh as an item of diet.—The flesh of the sheep does not appear to have entered largely into dietetics until quite recent times. Many wandering tribes in the East preferred the flesh of the horse and camel to that of the sheep, which even to the present day is not a favourite food in most countries—the British Isles being purely an exception. Apart from the animals killed in hunting by prehistoric man, he does not appear to have employed the domesticated animals as food, except in his periodical sacrifices to the Giver of all things. Later, animal food was considered as a luxury and as an indulgence not to be justified except on particular occasions. It was a long time before the generality of persons could be brought to feed on the flesh of the animals they had domesticated and habitually tended, and from which they derived so many advantages. This was no doubt eventually a part of their daily religion, as it is to-day in some parts of the East, especially among certain Indian castes.

The following passage is found in Pliny (secundus), and is translated by old Philemon Holland :—" Sheep likewise are in great request both in regard they serve as sacrifices to appease the Gods, and also by reason of their yielding so much profitable use : for even as men are beholden to the boeufe for their principal food and nourishment which they labour for, so must they acknowledge that they have their clothing and coverture for their bodies from the poore sheepe."

A quotation from an old English poet shall close this account of the sheep as food :—

" Poore beast that for defense of man at first created wast,
And in thy udder bearst the iuyce of dainty test;
That with thy fleece keeps off the cold that would our limbs assaille,
And rather with thy life than with thy death doest availl."

Numerous flocks.—There is abundant evidence that very early in the history of the world, man measured his wealth by the size of his flocks of sheep and herds of cattle. In the time of the Patriarch Abraham and his brother-in-law Lot, we read in the sacred history that, "the flocks of Abraham and Lot were so great that the land was not able to bear them." Job had 14,000 sheep besides oxen and camels. When the Israelites made an incursion into Midian, they brought away, besides other spoils, 72,000 beeves and 675,000 sheep. When the tribes of Reuben and Gad made war upon the Hagarites, they obtained as booty 250,000 sheep. The King of Moab rendered a yearly tribute of 200,000 sheep; and Solomon offered 120,000 sheep at the dedication of the temple. There are many other references to large flocks, but enough has been said to show that, in those far-off days, sheep existed in very large numbers and constituted no mean share of man's estate.

The first recorded improvement in Sheep breeding.—Most of the readers of this volume will be familiar with the story of how "Jacob served Laban seven years for the sake of Rachel, and they seemed to him but a few days, for the love of her;" and then, being deceived by Laban, he served for her another seven long years: at the expiration of that time, Laban offering him no wages, he was naturally anxious to return to his father. Laban, however, who was conscious that much of the prosperity that had lately attended him was attributable to the skilful and faithful service of his son-in-law, entreated him to remain, and Jacob consented on certain terms and conditions. The Bible wording of the common translation is not a little obscure; but the meaning, as understood by the parties, was this:—That in future, the speckled or ringstreaked sheep and goats—exceptions to the rule in colour, a brown or dingy black—should be considered as the wages of Jacob. These could have hitherto been very few, or the selfish and avaricious father-in-law would not have consented to the arrangement. The bargain was struck, and all the parti-coloured cattle and sheep were separated from the rest, and driven away to a distance of three days' journey, and placed under the care of Laban's sons, so that there could be no imposition or dishonesty; and the sheep of a uniform colour were left with Jacob.

He had probably witnessed the power of imagination at the moment of the female's conception, and had thought he might turn this, and not dishonestly, to his advantage, for the compact between them was sufficiently plain. "Jacob therefore took him rods of green poplar, and of hazel and the chestnut tree, and pilled white streaks in them, and made the white streaks appear which were in the rods, and he set the rods which he had pilled before the flocks in the gutters in the watering-troughs, when all the flocks, male and female, came to drink;" and they generally coupled before the watering-troughs. When by these means some speckled or ring-straked lambs had been dropped, he placed them in the sight of the other ewes—"he set the faces of the flocks towards the ring-straked," in order that they might produce the like.

It was only when the stronger sheep, those of the first yeaning, were in season, that he resorted to this expedient; the autumnal and weaker sheep were suffered to take their own course. The consequence

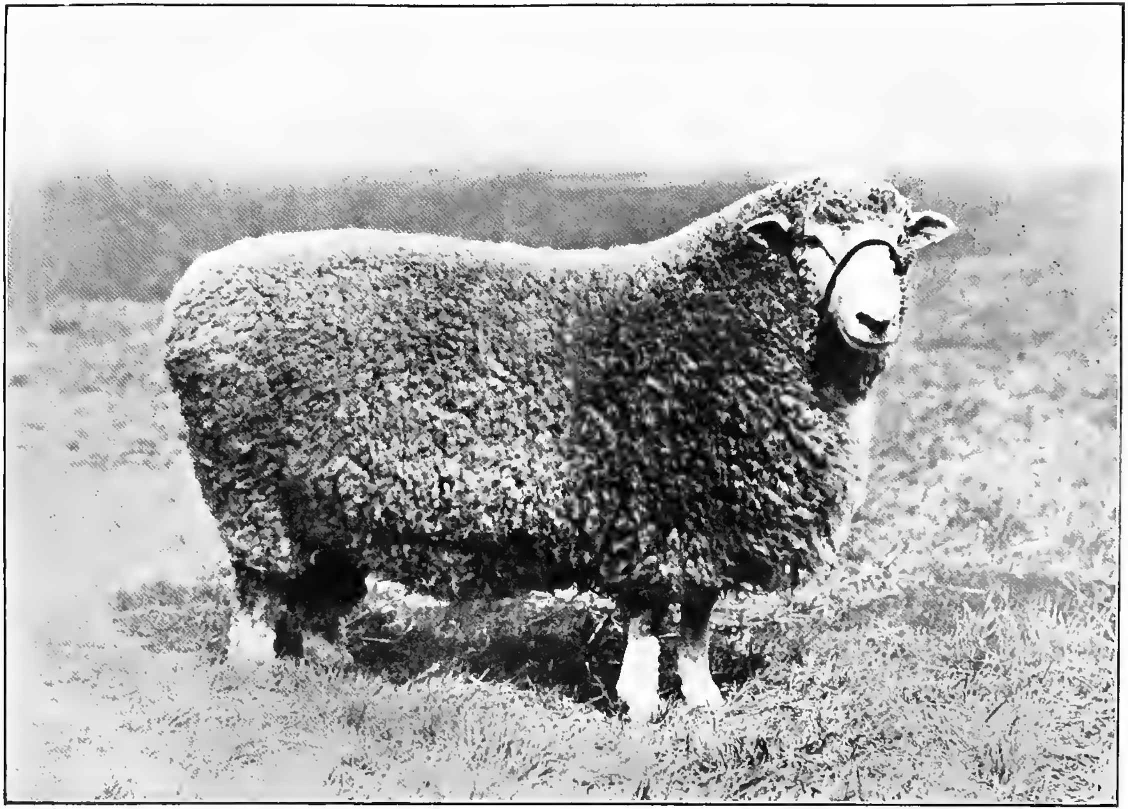

Plate 6.
Kent or Romsey Marsh Ram.

was, that either from the power of imagination in the mother, carried to an extent the like of which is not seen at the present day, or from some superior over-ruling agency, the flocks generally " brought forth cattle, ring-straked, speckled, and spotted."

Jacob's share of cattle and sheep increased bountifully, " the cattle were taken away from Laban and given to him, and the man increased exceedingly, and had much cattle, and maid servants, and men servants, and camels and asses." The reference to increase in maid servants and men servants is somewhat obscure, and it does not appear that they formed part of the original bargain.

Such is the first intelligence which the Scriptures afford us of the kind of sheep in those early years, or at least of those of which these flocks were composed: they were uniform in colour, brown or dingy black, and the exceptions were accidental and few in number. The experiment or policy of Jacob produced sheep of a new colour; they formed his numerous flock when he eventually quitted the service of Laban; some of them afterwards mingled with the flocks of Esau; they probably continued among the descendants of Jacob, and the better appearance of the fleece and the more varied purposes to which it might be devoted, would lead to a selection from those that had most white about them, until at length the fleece was purely white. It had become so in the time of King David, who likens it to snow; and Solomon speaks of the teeth of his mistress, as resembling a flock of sheep just come up from the washing.

It is not improbable that Jacob operated along similar lines in the matter of heredity to those enunciated by Abbot Mendl some thirty to forty years ago, and which are to-day being closely studied by Eugenists.

Dyeing and weaving.—It is possible that the earliest gathering of wool came from the cast-off wool during the moulting season; later the wool was plucked from the living sheep just previous to moulting; then the art of shearing would follow, probably in the first instance by cutting off the wool with a knife. Sheepshearing is of almost prehistoric date. Moses makes reference to "sheepshearers," Gen. xxxviii. 12, and in Exodus xxxvi. 19, refers to "rams' skins dyed red." Long before his time the art of weaving and dyeing had been established. The Egyptian dynasties had been ruling for some thousands of years anterior to the period of which Moses writes, and the tombs of those far off, almost prehistoric, kings of an ancient civilisation have yielded splendid examples of woven and dyed fabrics, which bear favourable comparison with modern productions.[1]

Enough has been said to demonstrate the fact, that sheep in the earliest history of man took a prominent if not a first place in the economy of his life, a place which time has not greatly displaced.

Prehistoric sheep in Africa.—A recent book by Sir H. H. Johnston, G.C.M.G., K.C.B., entitled

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[1] Some of the Biblical and other quotations have for convenience been extracted from the work by W. Youatt, 1827. This book may be picked up at a second-hand bookseller's for a shilling or two, and the student is advised to buy it if only for the mass of quaint information to be found therein.

"The Opening up of Africa," details in a lucid and interesting manner the domestic life of the early Egyptian settlements in the Nile Valley, which in a measure affords us authoritative information on the sheep in Africa.

Sir Harry says:[1] "When the dynastic Egyptians first settled in the valley of the Nile they had long-horned oxen (*Bos aegyptiacus*), dogs of the pariah, greyhounds, and perhaps hound breeds; and they tamed the wild sheep of the desert—*Ovis lervia*. . . . Soon after history begins the Egyptians are obviously discarding the semi-domesticated desert sheep, ibexes, oryxes, and gazelles in favour of the domestic goats and sheep which are being brought in from Syria and Arabia. These were of successive types. First came the hairy sheep with short horns, long legs, and a simple, long tail, which passed on westwards into Negro Africa and developed into the maned sheep we see to-day throughout West Africa and the Congo basin. Then came (from southern Arabia or Syria) the fat-tailed sheep with short horns or hornless. This found its way southward into Galaland, Abyssinia, Somaliland and Equatorial East Africa. A breed of it was carried by Hottentots into South-West Africa. In East and South-central Africa the maned and fat-tailed breeds of hairy sheep mingled into composite form. Next came into Egypt from the East a breed of large sheep with long hair and spiral horns growing out at right angles horizontally from the forehead. This breed travelled across the Sudan westward to Nigeria and also reached Abyssinia, but was otherwise foreign to Negro Africa.

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[1] See the work by Sir H. H. Johnston, "The opening up of Africa." Home University Library.

"About 2000 B.C. all these hairy breeds were superseded in Northern Africa by the introduction of woolly sheep from Syria and perhaps from Eastern Europe. Woolly sheep, though they extend throughout North Africa to Morocco and the oases of the Sahara, never penetrated into Negroland, except that they have reached the Niger basin in the vicinity of Timbuktu. The sheep of the Taureg are nearly always degenerate woolly sheep."

Ancient dignity of Shepherding.—The importance and dignity assumed by the ancient nomadic shepherd tribes in the days of Abraham must be briefly mentioned. Their power to influence the destinies of nations may be measured by the conquest of Egypt in the Sixteenth Dynasty by the Hyksos or Shepherd Kings, who it is presumed came from the East. This mysterious invasion founded that dynasty which bought Joseph from his brethren, but their career as kings had passed away before Moses led the tribes of Israel out of that bondage which was terminated by the great exodus of B.C. 1491, an event quite recent as compared with the Babylonian, Egyptian, and Minoan civilisations as disclosed to-day by excavation.

Early sheep in the British Isles.—Of the existence of prehistoric sheep in the British Isles nothing is definitely known, and many writers have hastily concluded because Julius Cæsar, B.C. 55, described

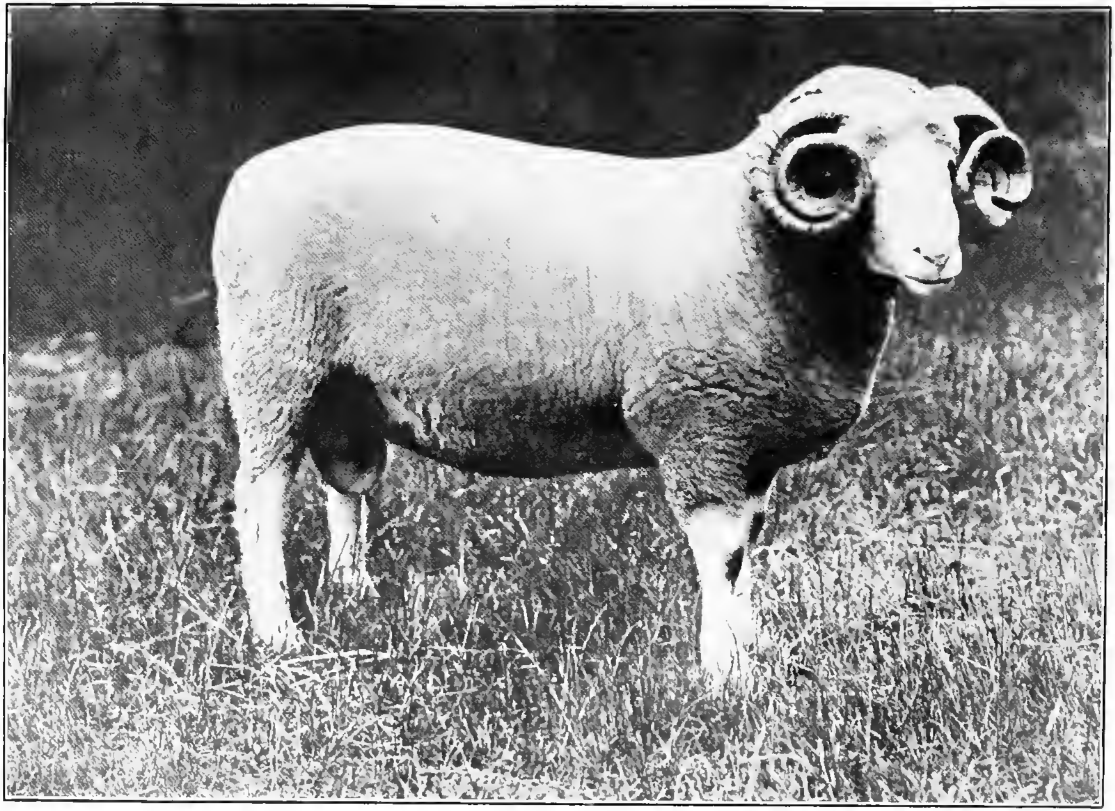

PLATE 7.
DORSET HORN RAM.

the habits and manners of such ancient Britons as opposed his landing on the Kentish shore in circumstantial language, without making reference directly to the existence of cattle and sheep, that not only were they non-existent but that the Britons were barbarians.

That these conclusions were entirely erroneous we propose to show.

It was customary among early civilisations for the warriors to go to battle unclothed and with their bodies decorated with grotesque designs in order to overawe their enemies (a feature which still prevails among certain uncivilised tribes). Hence their nakedness and lack of clothing would impress the more cultured Roman citizen, which fact has been perpetuated by their historians. Nevertheless the evidence now available is strongly in favour of the Britons having been well clothed.

Scattered throughout the length and breadth of the British Isles may be seen to-day evidences of an ancient civilisation which preceded the Roman invasion by many thousands of years. Prehistoric tumuli tell a tale of the burial places of great chiefs, whose remains after incineration were buried in urns of beautiful design. The cromlechs of massive proportions, like that at Stonehenge, are left to remind us of a prehistoric race of men with considerable brain power and imagination, who undertook feats of engineering such as would have appalled the Roman. Ancient forts upon the hilltops, especially in North Wales, remain in an excellent state of preservation to remind us that prehistoric man had developed a form of civilisation which follows the art of war. The men who undertook those great works cannot have been individuals of a mean type, to be classed as savages or barbarians, who knew not the comforts which follow usually in the wake of so-called civilisation.

The earliest recorded visits to these shores of peoples from the outer world, are those of that great Eastern commercial sea-faring race the Phœnicians, about 600 B.C. (Some investigators place their advent in these Isles so far back as 1200 B.C.) Their maritime power had flourished for many hundreds of years previously in northern Palestine, and their colonies had spread throughout the Mediterranean sea-board. For many centuries prior to their visit they had been obtaining the metals for which these Isles were famous, by overland routes. From that we must conclude that Britons were not unacquainted with the art of mining tin, iron, lead, gold, silver, and other precious metals. Although throughout all the records of the many visits of traders to these shores there is no mention of the importation of live animals, we know that the Phœnicians bartered for the skins of animals, and we may reasonably assume that the skins of sheep constituted part of that barter.[1]

Being inhabitants of an island, it is not surprising that Britons have been sailors from time immemorial, possessing substantially built sea-going craft capable of enabling them to carry on intercourse with adjacent countries, and, as we shall see, to form maritime leagues with the tribes sojourning there; while on their rivers they employed light wicker-work boats, square shaped and covered with skin, probably preserved in some way with oils or some species of varnish. These curious vessels survive at the present day upon many of the Welsh streams, and are called "coracles." The huts in some cases were built of reeds and probably covered with skins similarly treated to those on the coracles, and, if built of freestone as many of them were that remain with us as evidence, they would be thatched with straw or similar material.

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[1] "A popular History of the Ancient Britons." Rev. John Evans, B.A. 1901.

We may therefore reasonably conclude that the Britons, prior to the advent of the Phœnicians, were fairly advanced in civilisation and the appreciation of trade and commerce,[1] with its inevitable concomitant, war.

In 362-350 B.C. the Republic of Carthage, which was a colony originally peopled by and from Phœnicia, but had thrown off their allegiance—if it ever existed—became jealous of the aggressive Phœnicians in the matter of trade and seamanship. They requested one, Hamilco, to proceed on a voyage of exploration of the seas beyond the Pillars of Hercules (The Straits of Gibraltar), to proceed northward and endeavour to discover the Tin Isles, that Eldorado of minerals which up to that period had been the secret source of the Phœnician power and success. Hamilco returned after locating the Tin Isles, which he named the Isles Œstrymides, and speaks of them as being two days' sail from Ireland.

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[1] In the British Museum in the room appropriated to the exhibition of ancient British artifices in gold are numerous examples of very handsomely designed and executed torques or neck rings, a breastplate for a horse, etc., all worked in gold. Also a large collection of gold coins of pre-Roman date, evidencing a fairly high state of civilisation, and an appreciation of currency as a convenient method of trade. These finds have been unearthed in various parts of the British Isles.

Following quickly in the wake of the Carthaginian Hamilco came a new visitor from another of the off-shoot republics of Phœnicia—the Republic of Merchants established at Massilia, the modern Marseilles. The Massilian Republicans had doubtless heard of the success which had attended the voyage of Hamilco, and were in dire straits at the possibility of losing their overland trade in those ores received from the north *viâ* the Rivers Seine and Rhône; they determined to send out a fleet to explore for a direct connection by sea with the Tin Isles of the north. In 330 B.C. the fleet was fitted out and placed under the command of one named Pythias, an eminent mathematician, who followed the same route as Hamilco, but, being of a scientific mind and keen on exploration, visited many lands, even penetrating into the Baltic. In his observations of Britain, which he visited twice, he speaks of the cornfields and the methods of gathering the wheat into sheaves and storing them in large barns, where the threshing operations were performed, and he further notes that the country consisted mostly of marsh and forest, but there were open spaces cleared in the forest for the cattle and sheep, where they were kept and fed. This is the earliest reference to the existence of cattle and sheep and agriculture generally of which we have any authentic record in the British Isles.

It has escaped previous observers and readers of Cæsar's book, "De Bello Gallico," that he mentions the Belgic settlers as the introducers of agriculture into Britain, and that the wild settlers of the interior did not cultivate the land, but lived upon milk and flesh, and that cattle were abundant. There is recorded evidence that Cæsar did not penetrate many miles beyond the shores upon which he landed, and his evidence can only have been hearsay, gathered from such inhabitants whom he made prisoners in order to afford proof at Rome of his so-called conquest. Such prisoners would naturally not give him any evidence which would induce him to think that the land was any other than a poor one. It will be within the recollection of all students of history that the Romans only finally penetrated into Britain after the third attempt at conquest, about one hundred years after Cæsar's first invasion. Nevertheless, the statement was made by Cæsar that cattle, by which term all domestic animals are usually included which appear on the farms, were existing on the occasion of his first visit. It is also known to-day that at the time of Cæsar's visit tin was being mined in Cornwall, iron in the Forest of Dean, in Kent, and Sussex, where smelting was carried on extensively. The Britons were versed in the arts of war, possessing infantry and cavalry, also chariots, and arms consisting of swords, spears, bows and arrows, clubs, axes, etc., as recorded by Tacitus. They were versed in foreign policy, and alliances were formed for common defence, as witness their alliance with the powerful over-Channel tribe the Veneti. They were signatories of the celebrated Armorica or Maritime league which fitted out some 220 vessels to oppose the first Roman invasion. Such men could not be classed as barbarians!

After three attempts the Romans finally obtained a foothold in Britain about A.D. 41, and among the earliest developments was the establishment of a woollen factory at Winchester, where the art of spinning, dyeing, and weaving wool, as then carried on by more civilised nations, opened up a new era in the commercial life of Britain, which has continued uninterruptedly since then and has constantly developed as time went on.

The Winchester cloths would probably be spun from the short-woolled sheep surrounding the district, and from flocks which are the precursors of the West-down, Dorset, Wiltshire, and Sussex breeds of to-day. That the industry achieved considerable fame beyond the confines of Britain is confirmed by the Roman writer, Dionysius Alexandrinus, who stated, "The wool of Britain is often spun so fine that it is in a manner comparable to a spider's web." The clothes which were worn on state occasions and high ceremonies in Rome were said to have been made from cloths produced on British looms. Many other factories sprang up during the Roman occupation, in different parts of Britain, producing wools and cloths according to the class of sheep available. At Winchester, the manufacturers received for the first time a charter as "Fullers."

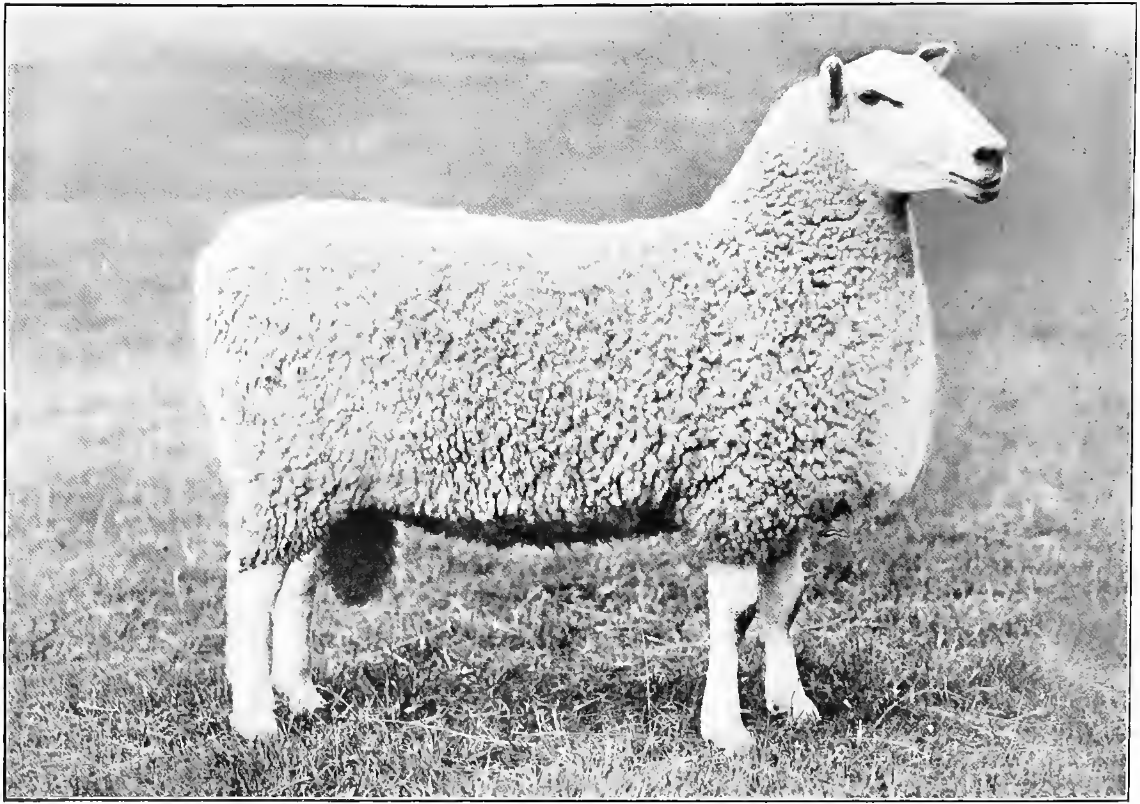

Plate 8.
Border Leicester Stirling Ram.

Wool, either in the raw or as productions of the spindle or loom, continued to hold a very prominent place in the commercial life and prosperity of Britain, and it is recorded that cash and wool were synonymous terms for many centuries. In history we have two curious incidents which confirm that statement. When Richard Cœur de Lion was taken prisoner by the Duke of Austria, the ransom was paid part in cash and part in wool. In 1342 King Edward redeemed his Queen Philippa's crown out of pawn at Cologne by shipping wool to the value of £2500.

In 1391 the export of wool had attained the enormous proportions of 47,320,000 lbs.[1] Prior to 1464 various breeds of English sheep had become distinctive and renowned; for in that year, King Edward IV. sent to Henry of Castile a present of Cotswold rams in order to improve the breed of the Spanish long-woolled sheep. Wool continued to hold its position until the introduction of silk in 1251, but the competition did not become acute until 1415, when by enactment the importation of wrought silk was forbidden into England. Later wool had to compete with flax, and finally cotton became a most formidable competitor.

The geographical position of the British Isles has lent itself to the production of what are called "county breeds." No part of the world can exhibit such a variety of classes or breeds, each possessing distinctive and indigenous features of wool, flesh, and pelt, as is the case in the British Isles; a fact which makes her to-day, as in the past, the premier agricultural country for the selection and purity of stock in the world. The reason of this remarkable state of affairs is to be found mainly in the fact, which has escaped attention generally, that for a thousand years and more no foreign army has overrun our land, devastating, pillaging, burning, and scattering the flocks or herds in its wake. The invasion of William the Conqueror, and the subsequent civil wars, were more or less family troubles, and did not materially disturb the calm development of agriculture along the recognised lines. Thus—viewing the position as one of the continental nations would do, and can speak with painful experience of invasion by a foreign foe, who marks his progress by burning farmsteads, pillaging, and scattering flocks until the breeds have become irretrievably merged one into the other—it may be reasonably assumed that these islands have practically enjoyed the blessings of uninterrupted peace for hundreds of decades, a fact not always appreciated as it should be by those who are for ever seeking a quarrel with neighbours. Verily we have to thank the Straits of Dover and the surrounding seas for that splendid isolation, glorious in that it has preserved to us that greatest of all blessings, "Peace within these Isles."

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[1] Youatt. "Sheep," p. 210.

Finally, in a minor degree, we owe a debt to King Edgar the Saxon for exterminating from his dominions, in the ninth century, the greatest of all sheep enemies, the wolf. The last wolf in Scotland was killed in 1680, and in Ireland in 1710.

CHAPTER III

BREEDS OF SHEEP, INCLUDING OBSERVATIONS ON CROSS-BREEDING AND FATTENING [1]

—"On superior pow'rs
Were we to press, inferior might on ours:
Or in full creation leave a void,
Where, one step broken, the great scale's destroyed:
From Nature's chain whatever link you strike,
Tenth, or ten thousandth, breaks the chain alike.
And, if each system in gradation roll
Alike essential to the amazing whole,
The least confusion but in one, not all
That system only, but the whole must fall."—POPE.

As in the case of other animals, the sheep is linked by certain well-defined characteristics with that of other semi-kindred animals. For instance—

The Musk Ox.[2]—Although presenting a certain superficial resemblance to the ox, the musk ox is nearly allied to the sheep. Its name is derived from the musky flavour which taints the flesh. It is the sole surviving representative of a distinct genus, *Ovibos moschatus*.

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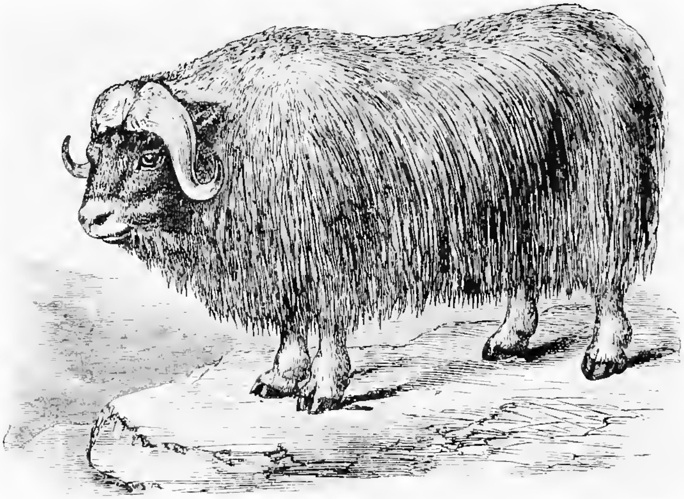
[1] The author has not dealt with the various breeds of British sheep at any great length because there exists an excellent work by Prof. Lydekker which treats of the whole subject very fully, and the volume should be in every sheepskin manufacturer's hands as a work of reference. It is entitled "The Sheep and its Cousins."

[2] The author has drawn upon the "Royal Natural History," by Professor Richard Lydekker, B.A., F.R.S., etc., for the information regarding the early breeds of sheep, and herewith desires to acknowledge his indebtedness.

The appearance of this animal resembles that of a large hairy ram, although covered with a thick coat of hair of a dark brown colour, which turns a lighter shade during the spring; underneath the hair there is a coat of fine soft wool of a light brown colour. The number of these interesting beasts to-day is small, and probably is becoming less as time goes by. Its home is in the desolate regions of the far north of the Western Hemisphere, where even in summer the surface of the ground scarcely thaws. At one period of the world's history they must have existed in larger numbers than they do to-day. They are essentially animals of the glacial period. Anterior to the Pleistocene period when the whole of the continent of North America was under



The Musk-Ox (*Ovibos moschatus*).

ice, the musk ox ranged as far south as Kansas, where its remains have been found between the 35th and 40th parallels of latitude. Remains of the musk ox of an extinct type have been found in Siberia, Russia, Würtemberg, France, the Pyrenees, Alps, Great Britain, and the Dogger Bank. It will thus be seen that this animal must have existed in considerable numbers at a time when the surfaces of those countries were under ice and snow. To-day it is the sport of hunters, and the huntsman who even sights a musk ox is considered extremely fortunate. Except as a scientific curiosity, this animal has no commercial value.

Sheep. Genus *Ovis.*—Sheep form a separate group, being distinguished by important characteristics; nevertheless, they again pass almost imperceptibly into the Goat group. In size they range from that of a small ox to that of an average-sized dog. The covering of the skin varies from coarse hair to fine wool. Some sheep possess no hair or wool, being hairless and are so classified. Another feature is the difference to be found in the absence of teeth in the upper jaw, which consists of a fibrous pad, sufficiently strong to retain the food between it and the teeth in the lower jaw. It is this characteristic which enables the sheep to crop the grass after other animals have grazed over it. In colour of wool, the variations as a rule are between black and white, with intermediate stages of grey; sometimes the wool assumes varying shades of brown. It is not improbable that they may trace their descent to extinct antelopes more or less nearly allied to that group.

The original stock of sheep is traced to, and represented by, eleven wild species which are mostly inhabitants of Europe and Asia northwards of the outer range of the Himalayas; one species occurs in the Punjab and Sind, and another in Northern Africa, and one in North America.

The American and Kamschatkan Wild Sheep (*Ovis canadensis and O. nivicola*).—The "big horn," *O. canadensis*, of America, and the Kamschatkan Wild sheep, *O. nivicola*, are two nearly allied species. The "big horn" is a large animal with a coat of a light brown colour, often showing a reddish tinge, which in winter is bluish grey on the surface. The underparts and a portion of the legs are white. The rams stand about 3½ feet high at the withers, and weigh about 350 lbs. or less. The ewes stand about 3 feet, and weigh about a third less than the rams who carry massive horns which in good specimens will measure as much as 40 inches in length. Formerly they were to be found in large flocks, but to-day are almost extinct.

The Kamschatkan wild sheep (*O. nivicola*) are to be found to the north of the Sea of Okhotsk, also in the peninsula of Kamschatka, which, as will be seen by reference to an atlas, is only separated from North America by the Behring Straits, which will explain the close connection between these two sheep. Like the "big horn," this breed is almost extinct.

The Mongolian and Tibetan Argalis (*Ovis ammon and O. hodgsoni*).—These really magnificent wild sheep are the inhabitants of that part of the globe, known as the "roof of the world," the higher ranges of mountains to the north of India; and thrive at an altitude from three thousand to four thousand feet. Like all wild sheep they possess immense horns, which are eagerly sought after and coveted by hunters; they also resemble the rest of the wild sheep in having much stature. Formerly they roamed over a considerable portion of Siberia, but have been hunted and driven back to the higher and more inaccessible mountains of Tibet. The sheep from Mongolia to the north of Pekin, described as *O. jubata*, are probably allied in species, and the same remark will apply to the Turkestan sheep, *O. nigrimontana*. The word Argali is the Mongolian name for sheep; in Kirghiz, it is Arkal.

THE SIBERIAN ARGALI SHEEP (*Ovis ammon*).
Natural History Museum, South Kensington.

The Pamir Wild Sheep (*Ovis poli*).—Originally discovered in the thirteenth century by the great

Venetian traveller, Marco Polo, but only in recent times (1873) made known to the world by the Russian naturalist Severtzeff, under the name of Karelin's sheep, *O. karelina.* The horns grow to a length of over 70 inches with a girth of 16 inches, to support these the sheep have necks of great thickness and very deep chest formation. The object of such large horns is to break the fall when springing or jumping from higher elevations and for defence. The weight of an adult ram will amount to as much as 500 lbs. The species which inhabit Baluchistan, Scinde, Afghanistan, and are also found in Eastern Persia, are known as *Ovis blandfordi.*

Head of the Siberian Argali Sheep (*Ovis ammon*).

The Armenian and Cyprian Sheep (*Ovis gmelini and O. ophion*).—These sheep are found in Eastern Persia, Asia Minor, the Cilician Taurus, and

Troodos mountains of Cyprus. In size they are smaller than the wild sheep already described, having only a height of some 30 inches and horns measuring from 26 to 40 inches in length. The species is almost extinct.

The Urial or Sha (*Ovis vignei*).—This is a typical wild sheep which has survived in the Punjab and stands about 2 feet 8 inches in height. The coating partakes of the fur variety rather than that of wool, and is of varying hues. It is to be found distributed over a wider area than almost any other variety of wild sheep in the Old World. It lives and thrives at the enormous altitudes of twelve thousand to fourteen thousand feet, under exceedingly rigorous climatic conditions.

The Mouflon (*Ovis musmon*).—This is the last of the typical wild sheep described in this chapter and is an inhabitant of Europe. At one time they existed in the islands of Corsica and Sardinia in large flocks, as many as five hundred being killed in a single hunt, but to-day not more than fifty or sixty are ever killed at one time. The method of hunting them is by organising big drives, and shooting them with a rifle, as when driven they are very difficult of approach, only long shots being obtainable. Occasionally wild mouflon will desert their own kin and live among tame sheep, while sometimes motherless domestic lambs have been known to seek companionship among a flock of mouflon. Evidently, as Lydekker says:—"the wild sheep are closely related to our domestic breeds." Splendid specimens of these wild sheep may be seen under domestication in most of the Zoological Gardens.

Before describing the domestic breeds, reference must be made to the two breeds of wild sheep, which form a connecting link with that of the goat (*Capra*).

The Bharal (*Ovis nahura*).—The Bharal is commonly known as the blue sheep of Tibet. In general appearance this animal resembles the goat, and is frequently so referred to, but in general particulars it is more closely allied to the sheep. Its colouring in the upper parts is brownish grey, that turns in the summer to a more distinct brown, while in the winter the tendency is to become grey; while the rest of the body is white. The coating would be more correctly described as fur rather than wool or hair. It stands about three feet high and possesses large

HEAD OF "UNICORN" BURWAL RAM.
Natural History Museum, South Kensington.

curled horns which at first grow upwards, then outwards and downwards.

The Barbary Sheep (*Ovis tragelaphus*).—This is essentially an African sheep and is not found elsewhere.

It possesses a mane and a great mass of long hair covering the throat, chest, and fore-limbs, with a tail having thick hair reaching below the hocks. It attains a height of over three feet, and is of a nearly uniform pale rufus yellow colour. They are numerous and are to be found extending from the Atlantic to Tunis, especially in the Atlas Mountains.

Both the Bharal and Barbary sheep are frequently to be seen in various Zoological Gardens.[1]

Domestic Sheep (*Ovis aries*).—The domestic sheep of Europe are probably descendants of the Mouflon or Armenian wild sheep; but there is much obscurity on this point, although there is a prevalent opinion that the features which are peculiar to the different breeds can only be accounted for by the supposition that they are derived, not from one common and single breed, but from several wild stocks.

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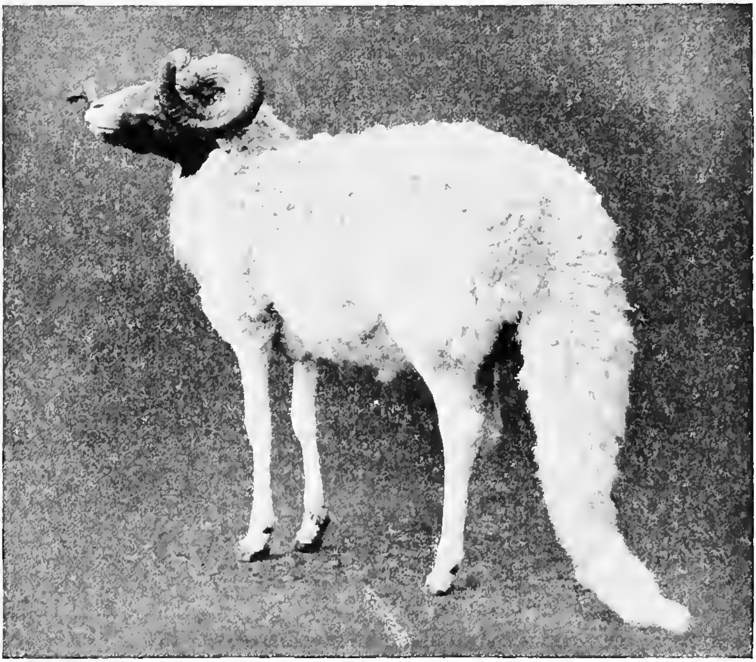
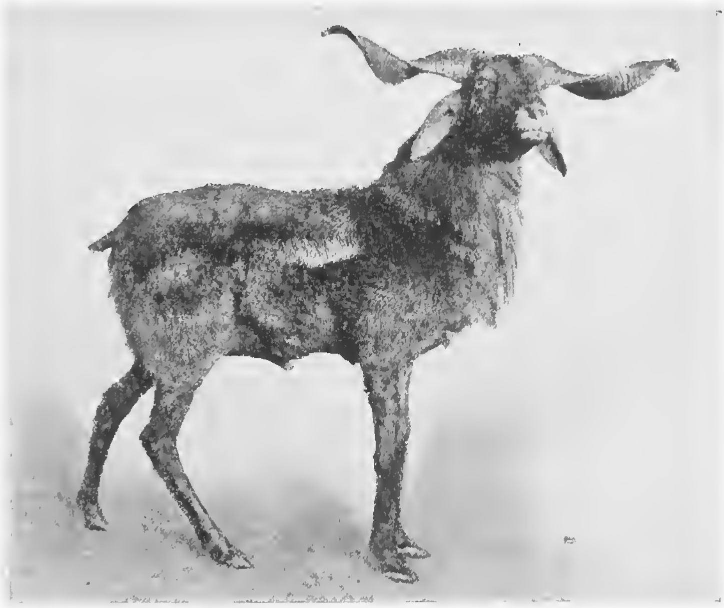
[1] The student who is interested in seeing specimens of the various wild sheep is recommended to proceed to the Natural History Museum, Cromwell Road, South Kensington, London. In the Pavilion at the end of the Lower Mammal Gallery and North Hall, in cases 46 to 48, he will see specimens of the following :—The Bighorn (1502). The Black Bighorn (*P. stonei*, 1053). The White Bighorn (*P. dalli*, 1054). The Grey Bighorn (*P. fannini*, 1070). The long-haired grey in same class, *O. borealis* (1055) and *O. nivicola* (1056). In the Argali class, *O. ammon* (1055), *O. hodgsoni* (1058), *O. littledalei* (1059), *O. sairensis* (1060). A magnificent specimen of Marco Polo's Sheep, *Ovis poli* (1061). The Urial (1063) of the Punjab, and in Ludak known as the Shapo (*Ovis vignei*) (1062). The Armenian wild sheep (1064), of which there are two additional representatives *O. gmelini erskinei* (1065), and *O. ophion* (1066). The Mouflon, *O. musimon* (1067). The Tibetan, a subgenus *Pseudöis* (1068), being the Bharal or Blue Sheep, *Ovis nahura*. The Barbary wild sheep or Arui, *Ovis lervia* (1069). The Student is advised to purchase the "Guide to the Great Game Animals (Ungulata)" from the Commissioner in the Central Hall (1s.), as it contains very interesting descriptions of each specimen exhibited.

One of the most remarkable of the many domesticated breeds is that to be seen in Eastern lands (Asia Minor and still further East, also in Africa), which is distinguished by the peculiarity of the tail being fat and long. So enormous is the tail that it frequently weighs as much as 50 lbs. and trails on the ground. In order to facilitate the progress of the sheep, the



Africander Fat-tailed Ram.

shepherd supports the tail on little sledges or on wheels.[1] The fat tail is considered a great delicacy by some nomadic tribes. Passing east, beyond the Caspian Sea into Persia and Central Asia, a breed of sheep is seen with the tail flat, short, and rudimentary, the fat having



HALF-BRED ABYSSINIAN MANED RAM.

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[1] Among the many wonders recorded by Herodotus (fifth century B.C.), he mentions Arabian sheep which had tails three cubits long, for which the shepherds made little trucks to keep them off the ground, each sheep having a truck of its own.

Herodotus also mentions another matter of interest to tanners who desire information regarding the antiquity of their craft. In writing of Crœsus the King of Lydia who, determined to commence a campaign against the all-powerful Persians, was in extremis approached by a sensible Lydian who desired to make a last effort to persuade Crœsus against the folly which finally caused his overthrow, the peacemaker uses as an argument—"O King, thou art about to march against men who have trousers of leather, and all the rest their dress of leather," etc.

accumulated on each side of the haunches in two great protuberances. This breed is designated *O. aries steatopyga.* This peculiar and interesting development of fat on certain parts of the body is not confined to the sheep, but is to be observed in the hump of the Indian Ox (*Bos indicus*), and in the development of abnormally fat calves in the legs of African bushmen. It would appear to be one of nature's wonderful provisions against drought and famine; such an accumulation of fat will sustain life, for example, while the flocks are crossing arid wastes where the fodder is scanty or non-existent. The fat-tailed species of sheep have found their way to regions south of the Zambesi river, even into Cape Colony, where they exist to-day, but not as a pure breed of fat-tailed sheep, for they have been crossed with European stock.[1]

Sheep are so widely distributed over the earth, that it will be quite impossible within the limits of this work to enumerate all the many and various breeds which have been in the main produced from imported stock, but have so altered in appearance, through environment, as to be unrecognisable as descendants from any given stock. Take the case of the Patagonian and Tierra del Fuego sheep; these are probably the largest sheep under domestication existing to-day, and yet they are not indigenous to that country.[2] The flocks are large, with very soft wool, but thin on the skin and light in grease. The climate is bitterly cold in winter, and more wind swept than any other land, yet the sheep run out in all weathers on the pastures, which are lean and poor except in favoured spots, where a species of alfalfa is plentiful. I am informed by a gentleman who visits the country regularly, and has

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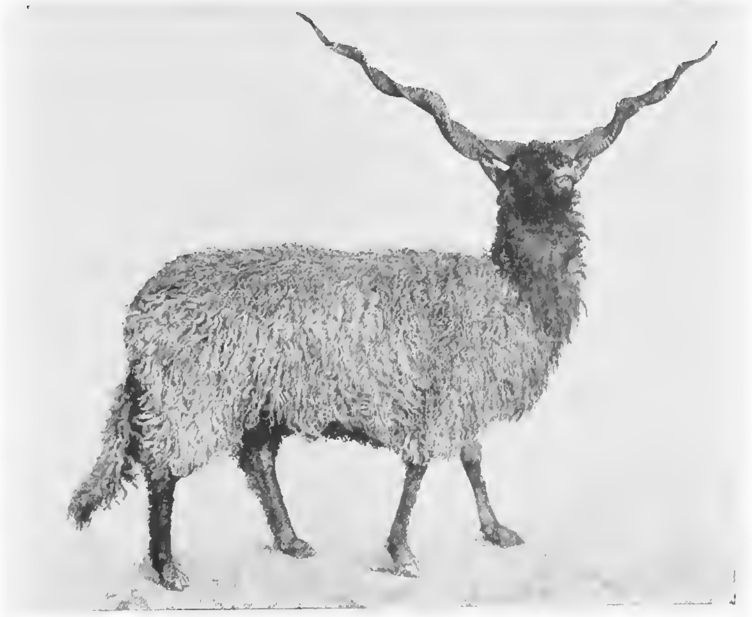
[1] "The Angola variety of the long-tailed race has also curious masses of fat on the back of the head and beneath the jaws." See "Youatt on Sheep," pp. 142 to 169, and Darwin's "Variations of Animals under Domestication," p. 116.

[2] Ulysses tells a remarkable story of his escape with his fellow sailors from the cave of the giant Polyphemus, one of a race of rude giant shepherds, known as Cyclops, and having but one eye. Their sheep were of equally gigantic



Wallachian Ram.
Natural History Museum, South Kensington.

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proportions. Polyphemus, after being blinded in his one and only eye by Ulysses, in his rage rolled the huge stone from the mouth of the cave, and let his sheep out, feeling among them for his captives. The gigantic sheep had been linked together cunningly, three abreast, and every middle sheep carried a Greek tied under his belly; Ulysses, after tying the last of his companions, escaped by clinging fast to the underwool of a large ram, the king of the flock. Polyphemus felt each sheep as it passed but failed to detect the Greeks, who thus escaped.

excellent opportunities for observation, that the sheep are crossed mainly with Rylands and Shropshire sheep, and in some instances with New Zealand merinos, probably Corriodale. Mange and sheep-scab are prevalent, but ticks and other insects, like flies, do not seem to find a congenial nest; this is possibly due to the excessive cold and winds.

Four-horned Piebald Ram.
Natural History Museum, South Kensington.

New Zealand sheep are invariably all crossed from imported stock, being non-indigenous to that country; and the crosses are made from Shropshire, South Down, Leicester, Border Leicester, Lincoln, and Romney sheep. These inhabit the lower lands, while in the higher lands there are still a fair number of merinos or merino-cross-breds, from crosses with the before-mentioned breeds.

The Australian sheep are in the main merino, and, like all that class of sheep, are not considered suitable for the export trade in chilled or frozen mutton, but are boiled down for the fat which exists in the body in greater quantity than in any other breed of sheep; the fat is not confined to the body but permeates the skin and wool to a corresponding degree. Australia possesses similar breeds to those in New Zealand, hence the well-known and very extensive mutton export trade.

Four-horned Manx Loaghtan Ram.

In Patagonia efforts are being made to reduce the size of the sheep and increase the quantity and quality of the wool by suitable crossing with approved stock, probably also in order to develop the export trade in chilled mutton.

The domestic sheep of North America and the northern countries of South America, are in all cases originally from imported European sheep, crossed, thus developing a new series of breeds which are peculiar to given States. Apart from the act of crossing, local feed and environment play an all-important part in creating various phases of breeds. If we are to comprehend the great changes which have been brought about by the domestication of the wild sheep in prehistoric times, and the production of the present domestic sheep, it must be recognised that evolution is not all progress, and life development is not always attended by advance. It is generally recognised by biologists that the great forces which determine the fate of a living species are (1) development or advance, which implies raising the scale of life ; (2) the state of stability, which means maintaining the same conditions, unchanged and unaltered, and (3) the period of degeneration, the state of greater simplicity.

It does not necessarily follow that only one of these three states, "development," "stability," and "degeneration," should be present at one time; all three may be active and present in the one animal and at the same time, although these would be more marked after several generations. It is possible through these three states, to diagnose and explain many, if not all, of the changes which have taken place in the sheep species. For example, all wild sheep had, or have, horns in both sexes, for the purposes of defence and assistance in landing when springing from a great height;[1] assuming that such animals, when young, are placed among tame sheep for domestication, or are otherwise tamed, in course of generations the size of their horns will decrease from misuse, until, after further lapse of time, they will disappear altogether; it is one of the penalties which nature exacts for idleness. That is degeneration, and such degeneration in its wider application has been studied and cultivated by shepherds to produce certain features in given breeds. The late Charles Darwin, in his valuable work "The variation of Animals and Plants under Domestication,"[2] pp. 114–123, treats the subject in relation to sheep, and the student desiring to educate himself on this subject cannot consult a higher authority.

It is scarcely necessary to refer more than briefly to the many and various breeds of sheep in the British Isles, because they have been so ably treated *in extenso* by several writers.[3]

British Breeds of Sheep.[4]—The breeds of sheep in the British Isles are graduated by the authorities as follows :—

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[1] Telemachus, when narrating his travels, says:—

"Sidon and Ethiopia I have seen
Even to Erembus roamed, and Lybia, where
The *lambs are full-horned from their birth,* I wean,
And in the rolling year the fruitful flocks *thrice yean.*"
HOMER'S "ODYSSEY."

[2] See popular edition by John Murray, price 2*s.* 6*d.*

[3] Youatt, Spooner, and Lydekker.

[4] Many of the modern domestic sheep are to be seen in the Natural History Museum, South Kensington, in the Central and North Halls, and are well worth a visit from the student. The list is too long to mention here. The descriptive "Guide to the Domesticated Animals," may be purchased from the Commissioner in the entrance hall, price sixpence.

The short-tailed sheep of the Orkney and Shetland Isles, whose fleece is composed of fine, soft wool intermixed with hair. Hardy of disposition, with horns frequently in both sexes. The colour may be either black, brown, grey, or white.

The sheep of Wales are divided into (1) Higher Mountain, (2) Soft-woolled, (3) The Old Radnor, (4) The Radnor. These four breeds may for all practical purposes be grouped into two classes, the sheep of the higher mountains and those of the lower ranges. They are small in size, hardy, and noted for the delicacy of their flesh. The wool is soft and frequently mixed with hair or kemp.

The forest and mountain sheep of England, the Exmoor and the Dartmoor, may be classed with the Black-faced Heath sheep of Derbyshire, Cumberland, Lancashire, Westmoreland, Yorkshire, and up to the south of Scotland; these classes would comprise the Herdwicks of Cumberland and Westmoreland, the Lonk of the North of England, the Penistone of Yorkshire, Lancashire and Derbyshire, the Ancient Upland breeds, and the Cheviots.

The second great class of sheep may be enumerated as follows :—

The Old Norfolk, Dorset, Somerset, Portland, Old Wiltshire, Old Hampshire, Old Berkshire, Hampshire Down, Wiltshire Down, South Down, or Sussex, the Shropshire, the Ryeland long-woolled, Lincoln old and new, Romney Marsh, Teeswater old and new, Bampton

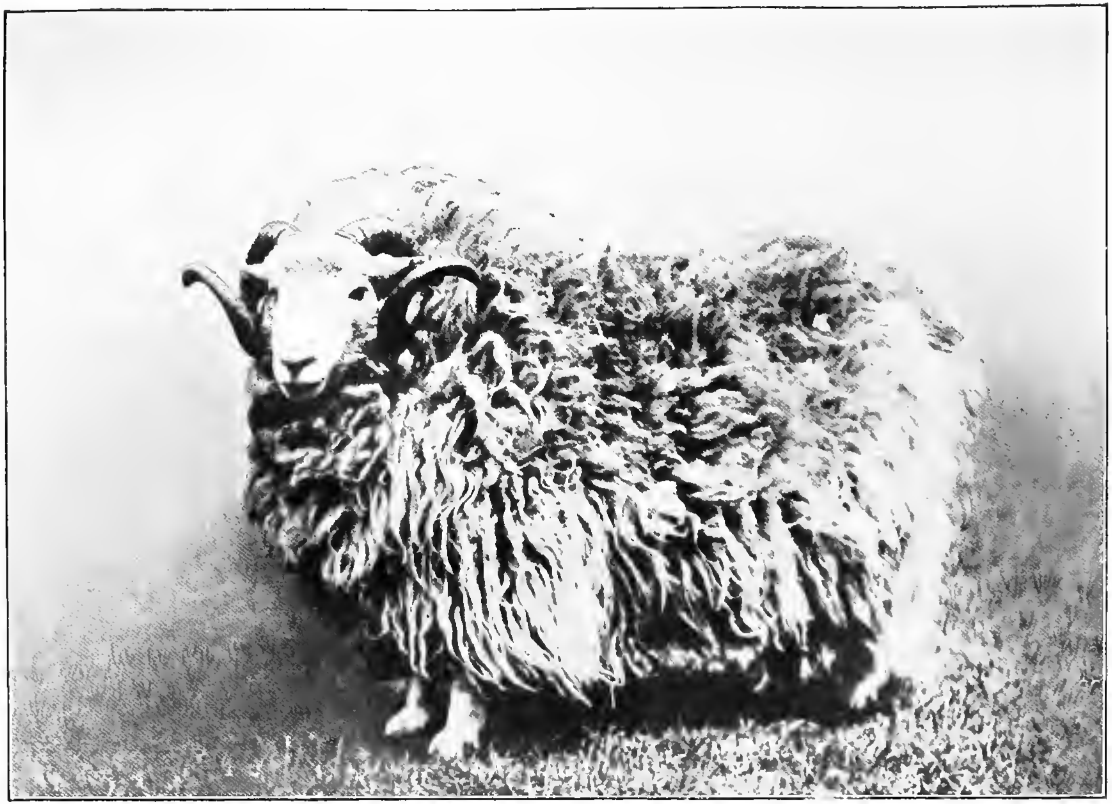

Plate 9.
Herdwick Ram.

Nott, Devonshire South Hams, Cotswold, New Oxford, and the Leicester, old and new.

Ireland is the home of the Wicklow, Kerry, and the long-woolled sheep.

The foregoing does not enumerate all the various breeds to be found in the British Isles, but may reasonably be assumed to comprise at least the representative groupings from which the many cross-breeds have sprung.

Character and Physiology of the Sheepskin.—The character and physiology of the skins yielded by the many varieties of sheep depend in a large measure on their environment and the class of food obtainable. As a rule, and it may be accepted as a guide, the fine soft-woolled sheep possess a delicate grain and a soft pelt. The outer layer of the pelt is commonly referred to by the workman engaged in the sheepskin industry as the "grain," which in such pelts is extremely thin and delicate, and liable to rupture during the removal of the wool, while from causes of incipient decay, what are sometimes called "pinholes" may be readily perceived on the surface after dewoolling, and which, as a matter of fact, penetrate some distance below the grain. After dewoolling a merino woolskin shows this defect in a marked manner.

The long-woolled sheep have a tougher and coarser grain, with a thicker and larger pelt frequently charged with fat to an extent which is absent in mountain breeds. Such pelts being fuller in substance are sought after for splitting purposes.

The mountainous breeds possess fine soft wool, which is nearly always accompanied by short hair or kemp. The grain is fine and goatlike in appearance, tough, with a substructure compact and remarkably free from the excess of fat, while the area of skin is smaller than that prevailing among the lowland breeds of sheepskins. The latter, while not possessing the superficial area of skin of the long-woolled sheep, have a grain varying in degrees of texture between tough and coarse to the delicate and fine grains seen in the Shropshire sheep. In all classes of this type of pelt, fat exists in varying proportions as to quantity.

The sheep of such countries as Arabia, Asia Minor, etc., are spready and thin, with usually hard tough grains, being sufficiently devoid of excess of fat as not to cause any inconvenience to the tanner, and are sought after for such uses as chrome sheep, to produce the imitations of glazed kid.

It is a curious fact that the skins of fat-tailed and fat-buttock sheep as a rule contain so very little fat as to enable them to be introduced into the arts without degreasing.

Cross-breeding and Fattening.—The origin of our county breeds of sheep may be sought in the fact that, in the earlier times, the sheep were bred entirely for the purpose of obtaining a special class or sort of wool; this selection of wool produced from local sheep was hand-spun and woven into cloths which gained fame for the locality. Many of these ancient industries survive to the present day, and attempts are being made, where they have become defunct, to revive them. There cannot be any doubt that the old hand-spun and woven cloths prepared from local wools wore longer than the machine-made cloths of to-day, while, on the other hand, they lacked the fine spinning and very varied patterns and hues which are now seen as the outcome of mechanical inventions and the application of chemistry in dyeing.

To breed sheep for their flesh was originally a minor industry, whereas for years past it has formed one of the greatest sources of profit especially among the caterers for the British public, who are the largest consumers of mutton in the world. The production of a heavy carcase in the minimum of time, together with the maximum weight of wool, has become of paramount importance to the stock-raiser. Britain no longer provides her teeming population with all the flesh food she consumes; her oversea dominions and the Argentine Republic have made sheep-raising into a fine art, large killing and freezing companies have been formed with millions of pounds sterling of capital, in order to provide the best of meats for the hungry millions of Great Britain and other countries.

These countries, in order to secure the result to which their energies and abilities have been so admirably directed, have resorted to a systematic scheme of cross-breeding with imported sheep, the object being to obtain the maximum yield of wool and flesh with the minimum of deaths from disease or natural causes.

The demand for mutton has caused the various veterinary, agricultural, and kindred societies to turn their attention to the question of cross-breeding in the

British Isles. The importance of this movement from the sheepskin tanner's point of view is of the greatest moment, and cannot be passed over without full investigation, because the changes which have been brought about by increasing the weight of wool and carcase have been accomplished, not under the old natural conditions of feed, but through the study of the effect of artificial feeding with one or more of the many excellent artificial foodstuffs which are being manufactured and compounded under the most improved scientific conditions by large and important firms, whose staff of ably trained and qualified experts are in a position to comply with any demand for a special food for a given requirement. I am told by reliable agriculturists that they can fatten sheep for the markets in ten months, possessing the same weight of wool and flesh as were formerly produced in two years under the pre-existing conditions of natural feeding.

The tanners of sheepskins cannot complain with any justice against such a course of action, however much they may deplore the change, because the times in which we live are strenuous, and the profits, when made, have to be obtained either by increasing the turnover or by more rapid production.

Up to the middle of last century there had been but little disturbance of the breeds by crossing, and no serious attempts were made to organise artificial fattening until the late 'seventies; in the 'eighties the system of crossing and fattening had become well established, and proceeds apace to-day. Mr. Muir, an authority on sheep, says: "Pure *v.* Cross-bred

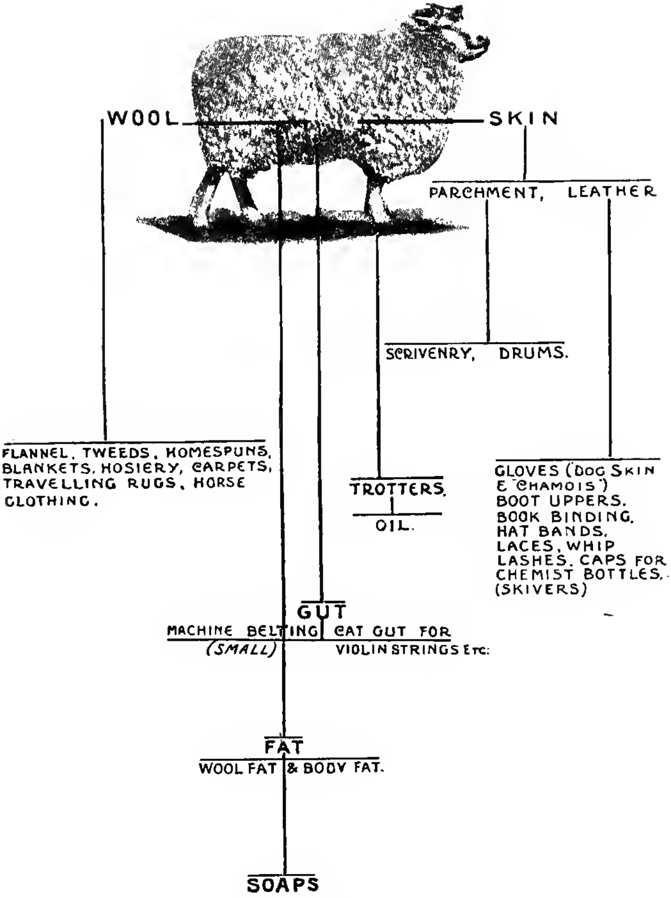
WOOL
SKIN
PARCHMENT, LEATHER
SCRIVENRY, DRUMS.
FLANNEL, TWEEDS, HOMESPUNS, BLANKETS, HOSIERY, CARPETS, TRAVELLING RUGS, HORSE CLOTHING.
TROTTERS.
OIL.
GLOVES (DOG SKIN & CHAMOIS)
BOOT UPPERS.
BOOK BINDING.
HAT BANDS.
LACES, WHIP LASHES. CAPS FOR CHEMIST BOTTLES.
(SKIVERS)
GUT
MACHINE BELTING (SMALL)
CAT GUT FOR VIOLIN STRINGS ETC:
FAT
WOOL FAT & BODY FAT.
SOAPS

PLATE 10.

Assuming sheep are primarily grown for their flesh, the above instructive diagram illustrates the valuable bye products.

The author is indebted to Mr. McCartney-Filgate for his kind permission to reproduce this diagram.

Sheep. Probably the numbers of both are about equal, as the crossing of sheep is a proceeding carried on to a much greater extent than many approve of. It is generally accepted as a fact that few or no breeds are improved by crossing, and that their value is always reduced by the process, as for stock purposes pure-breds are invariably preferred. . . . Cross-breeding. Although not in favour of this to the extent it is often gone to, the practice is too fully established to be either stemmed or diverted, and crossing will go on under the impression that extra gain will result."

In considering the question of crossing sheep, it must be borne in mind that it is, in most cases, absolutely necessary in the oversea countries to effect a cross, in order that the sheep may survive. Darwin states that the British sheep will not thrive in France. Youatt enunciates the well-known fact that sheep removed from a torrid zone to the Zoological Gardens, London, failed to survive the second year; and shepherds are aware that, if lowland sheep are moved into the mountains, they die of phthisis, and if mountain sheep are transferred to rich lowland pasturage they do not thrive. The sheep is essentially a creature of environment, hence it is of the very greatest importance to secure such a cross as will stand the change in environment in the oversea lands; even the best and most successful cross-breds will tend to revert back to the original stock on one side, whichever may be the strongest.

In considering the questions affecting crossing or fattening sheep, the stock-raiser never gives a moment's thought to the effect produced upon the skin. The wool and flesh alone interest him ; the skin being to him a valueless commodity, a necessary covering to support the wool during growth. To the tanner who formerly looked to certain breeds to yield given grain characteristics, or, for splitting purposes a solid substructure, the changes wrought by crossing and fattening by artificial means cannot be neglected. The alterations in grain, fibre, and amount of fat deposited are questions for careful study, in order that the old processes in the tannery may be altered, if possible, to meet the changed conditions.

To afford some idea of the far-reaching efforts which are being made to produce a greater weight in sheep, it would be useful to refer to the mountain sheep of Wales, which have been noted from time immemorial for a special flavour and sweetness of flesh. At the agricultural farm connected with the University College of North Wales, the late Prof. Winter carried out for years experiments in crossing the Welsh ewes with such breeds as South Downs, Dorset-horned, Ryeland, and Kerry Hill rams, in order to obtain a strain that would live and thrive under the rough atmospheric conditions of Welsh mountain life. In this he was wonderfully successful, as the published results and prizes obtained at the various agricultural exhibitions prove. These strains are being introduced into some mountainous districts, with a consequent change in the character of the skin. Unless new blood is being introduced into the same cross-breds from time to time, it is quite possible the strain will eventually revert back to the original Welsh. Nevertheless, anxiety must prevail among sheepskin tanners regarding these subtle changes.

Sheepskin Fats.—Probably to a greater extent even than crossing, that of artificial fattening of sheep has reached a fine art, possibly because the results are obtained quicker and with less trouble and greater certainty than is the case with crossing. The prime object in forced feeding is to ensure early maturity of the lamb for the market, and the students at the various colleges which specialise in agriculture are taught the principles under which this desired object can be most readily obtained, which will vary according to the local conditions and the special kind of food selected.

A large proportion of the skins which to-day pass the pelt (denuded woolskin) sorter's inspection are but early matured lambs, the production of forced feeding, and such pelts are frequently of sufficient size to enable them to be passed as sheep. Again, to quote from Mr. Muir,[1] "Old fashions have changed. The tendency of to-day is to get all edible stock matured, perfected in condition, and sold off at a much earlier age than in olden times. This rapid system is much applied to sheep, with especial advantage to the feeder. The old idea was that prime wether mutton was unattainable till the sheep was three to four years old; but now ripe four-year-olds are rarely met with. Three-year-olds are not often seen; two-year-olds are also declining,

[1] "Sheep," by James H. Muir.

and *one-year-olds are fast becoming the mutton of disposal.* Consumers do not object to it, while quick returns suit the feeder, and *weights are made in the first year that exceed all succeeding years.*"

The sheep is an excellent feeder, always eating as though possessed of an insatiable hunger, a feature the stockraiser is not slow to take full advantage of and feeds accordingly. The total amount of fat which a sheep will make, when fattened and ready for the market, will amount to as much as from 25 per cent. to 30 per cent. of its weight. During the process of digesting the mass of food, the surplus fat beyond that required to supply the heat necessary for the upkeep of the wear and tear of the body, overflows into the outlying tissues; a large proportion entering the skin through the countless miles of blood capillaries, and that share which is not immediately absorbed by the wool is stored up in the skin.[1]

Professors Schaefer and Thane[2] (pp. 235, 236), who are authorities on this question, say: "By far the greater part of the fat of the body is enclosed in cells of the areolar tissue, which, together with the fibres and blood-vessels which pass between them and serve to bind them together, constitute the adipose tissue. This tissue is not confined to any one region or organ,

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[1] The Rev. Dr. Edmund Cartwright, the inventor of the Power Loom, called attention in the first years of the nineteenth century to the effect of sugar as a fattening material for sheep, and his experiments showed that it was then profitable, provided sugar did not exceed fourpence per pound. This discovery has been made good use of to-day by the artificial food purveyors for animals.

[2] Quain's "Anatomy."

PLATE 11.

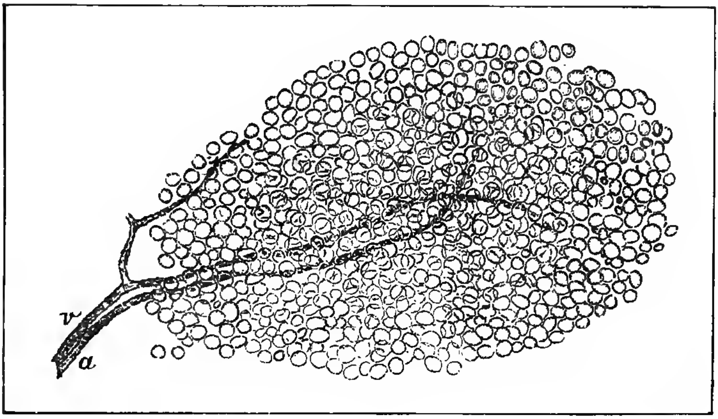
A small fat-lobule from the subcutaneous tissue of the guinea-pig, magnified about 20 diameters (E.A.S.).

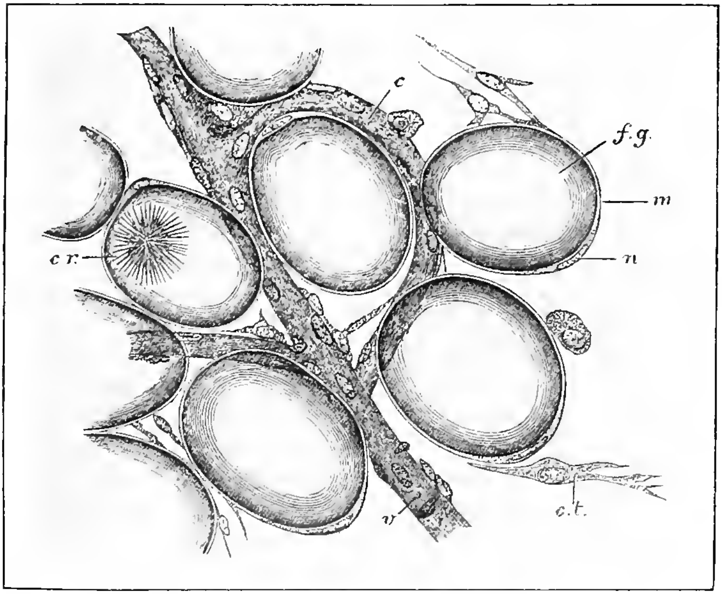
a, Small artery distributed to the lobule; *v*, small vein; the capillaries within the lobule are not visible.—*From Quain's " Anatomy."*

PLATE 12.

A few cells from the margin of the fat lobule represented in the preceding figure; highly magnified (E.A.S.).

f.g., Fat globule distending fat-cell; *n*, nucleus; *m*, membranous envelope of the fat-cell: *cr.* bunch of crystals within a fat-cell; *c*, capillary vessel; *v*, venule; *c.t.*, connective tissue cell; the fibres of the connective tissue are not represented.—*From Quain's " Anatomy."*


v
a


c
f.g.
m
c r.
n
v
c.t.

but exists very generally throughout the body, accompanying the still more widely distributed areolar tissue in most, if not in all parts in which the latter is found. Still its distribution is not uniform, and there are certain situations in which it is collected more abundantly. It forms a considerable layer underneath the skin, and, together with the subcutaneous areolar tissue in which it is lodged, constitutes in this situation what has been called the *panniculus adiposus.*

"**Structure.**—When subjected to the microscope, the adipose tissue is seen to consist of small vesicles, filled with an oily matter, and for the most part lodged in the meshes of the areolar tissue. The vesicles are most commonly collected into little lobular clusters (Plate 11), and these again into the little lumps of fat which we see with the naked eye, and which in some parts are aggregated into round or irregular masses of considerable magnitude. Sometimes the vesicles, though grouped together, have less of a clustered arrangement than when they collect alongside of the minute blood-vessels of thin membranous parts.

"In well-nourished bodies the vesicles or fat-cells are round or oval (Plate 12), unless where packed closely together, in which case they acquire an angular figure, and bear striking resemblance to the cells of vegetable tissues. The greater number of them are from $\frac{1}{300}$ to $\frac{1}{600}$ of an inch in diameter, but many exceed or fall short of this measurement. Each one consists of a very delicate envelope (*m*), inclosing the oily matter, which, completely filling the envelope, appears as a single drop (*f.g.*). It often happens that a part of the fatty contents solidifies in the cell after death, forming a bunch of needle-shaped crystals (Plate 12, *cr*)."

"The areolar tissue connects and surrounds the larger lumps of fat, but forms no special envelope to the smaller clusters; and although fine fasciculi and filaments of that tissue pass irregularly over and through the clusters, yet it is probable that the vesicles are held together in these groups mainly by the fine network of capillary vessels distributed to them.

"The adipose tissue is copiously supplied with *blood-vessels.* The larger branches of these pass into the fat-lumps, where they run between the lobules and divide, till at length a little artery and vein are sent to each small lobule (Plate 11, a, v,) dividing into a network of capillary vessels, which pass between the vesicles in all directions, supporting and connecting them. The *lymphatics* of the fat are in close relation to the blood-vessels accompanying them as they enter the lobule."

Professors Schaefer and Thane's observations were made upon human bodies, but the principles they lay down apply with equal if not greater force to the disposition of fat in the sheepskin.

The mass of deposits of fat in the skin exist in the *fatty layer* or *stratum adiposum*, which is that portion of the skin in which the wool-roots are buried and have their birth. This is also the layer in which all the looseness of sheepskins occurs, and, as will be readily seen, is caused by the excess of fat deposited and subsequent destruction of the more delicate tissues.

Three kinds of fat exist in the woolskin; viz. skin

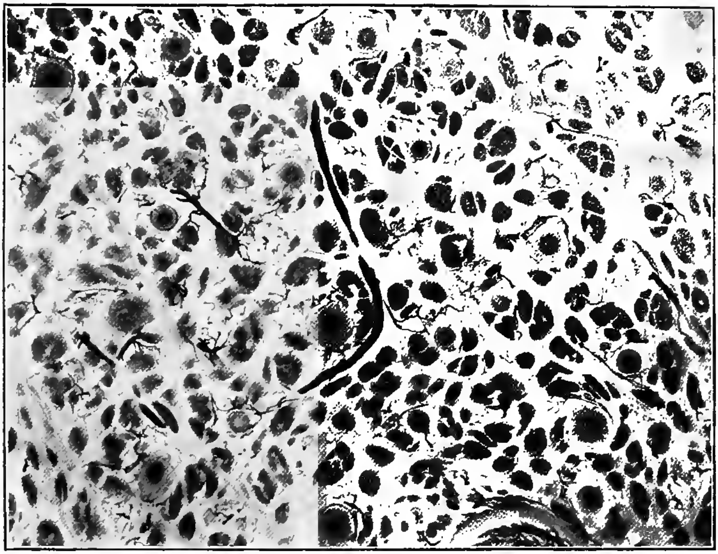


Plate 13.

A highly magnified horizontal section of human skin cut through the fatty layer, and stained by Dr. Drinkwater of Wrexham.

The round spots are hair follicles containing hairs and blood capillaries. The surrounding but more irregularly shaped spots are fat lobules, which by examination with a hand glass appear as bunches of cells not unlike bunches of grapes. The black lines are blood vessels.

This picture will afford some idea of the heavy distribution of fat in the fatty layer. The larger spots represent the full bunches cut through the centre, while the smaller sized will be bunches either in the next upper or lower strata of fat lobules.

From a photo-micrograph by the author.

fat, sebaceous fat, and wool fat. All must have a common origin, but our knowledge of fat metabolism in the skin is as yet wholly inadequate to permit of a discussion of the subject in these pages. Suffice it to say, that three stages of the process may be distinguished, viz. the tallow fats of the skin, the lanoline fats of the wool and the intermediate cockle fats. It is conceivable, that the tallow fats, containing among other things, the glycerides of the unsaturated oleic and linoleic acids, and even, be it said, linolenic acid, may become hydroxy acids by the action of water and oxygen ; that the cockle fats may be of this nature, and that these again degenerate into unsaturated unsaponifiable fats of the iso-cholesterol series ; although this latter process would involve the attribution of a reducing action to some substance or substances incorporated in the wool.

The importance of the study of fat metabolism cannot be over estimated, and an extended research in this direction would solve many difficulties which at present puzzle not only the sheepskin manufacturer, but his heavy leather confrère.

"Colt" or "Dead-fat" in Sheepskins.—In conclusion, the question of "Colt" or "Dead-fat" in sheepskins must be briefly mentioned. This curious phenomenon, well known to every one engaged in handling sheep pelts, has mystified scientific thinkers for years.

It is undoubtedly a species of adipose degeneration of the individual cell, and is intimately connected with the hydrolysis of the protein and glyceride molecules on the death of the cell; this hydrolysis, of course, resulting in the production of crystalloidal or semi-crystalloidal bodies. This view is supported by Professors Schaefer and Thane (Plate 12, cr.) who give the following opinion: "It often happens that a part of the fatty contents solidifies in the cell after death, forming a bunch of needle-shaped crystals." It would be interesting to decide analytically whether such crystals were those of one or more of the higher members of the fatty acid series, as it seems probable that enzyme hydrolysis such as obviously takes place would be of a lipolytic character, a fact which it would not be difficult to establish.

The fat is contained in living cells, and is a very necessary bye-product of, and adjunct to, the cell life and vital action, as during periods of inanition and also frequently during normal development, the steapsin of the pancreatic juices is utilised to hydrolise these glycerides for use in maintaining the tissues and fleece.

A sheepskin possessing a surplus of fat, as it frequently does along the spinal column, especially in the neck, is liable, while resting among other wool-skins in a pile, to heat and putrefy quicker than if it had been properly cured, rise of temperature or general atmospheric humidity of course facilitating such change. Under such circumstances, cell action will rapidly diminish and ultimately cease, *the death of the cell thus taking place*, and the large colloidal aggregates can no longer be maintained. Contracting and subsequent subdivision take place, involving the rupture of the

PLATE 14.

A section cut from a sheep skin showing "colt."

This section was cut from a limed pelt, unhardened, and subsequently stained with osmic acid to show up the fat as black markings. It will be noticed in the lower part of the section a number of upright black columnar markings, resting upon a black base of connective tissue, the flesh. The columns are the "colt" referred to which have burst their cell walls and overflowed upward and downward. In one situation the entire colt column has been removed by the act of cutting. Striations of the colt fat will be seen extending up towards the grain, which is that part seen in the top of the section. Just below the grain surface, smaller and more or less round black markings will be noticed. These are the groups of sebaceous glands containing fat. The microscope showed the colt fat as crystalline in character.

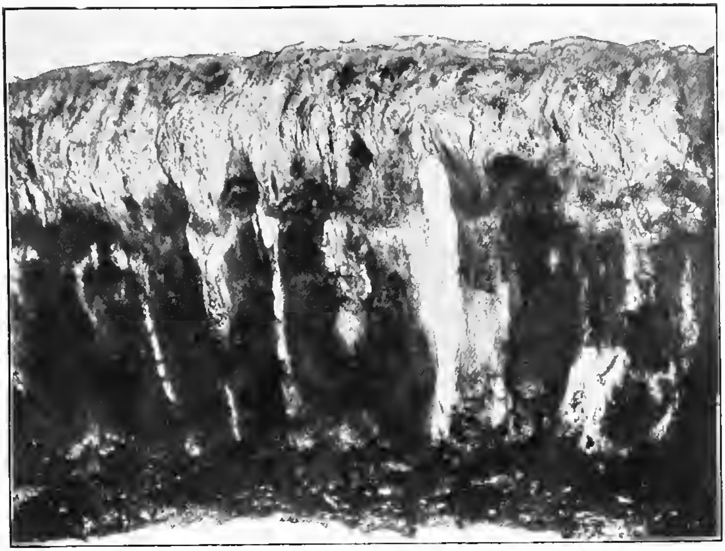
Plate 14, highly magnified.

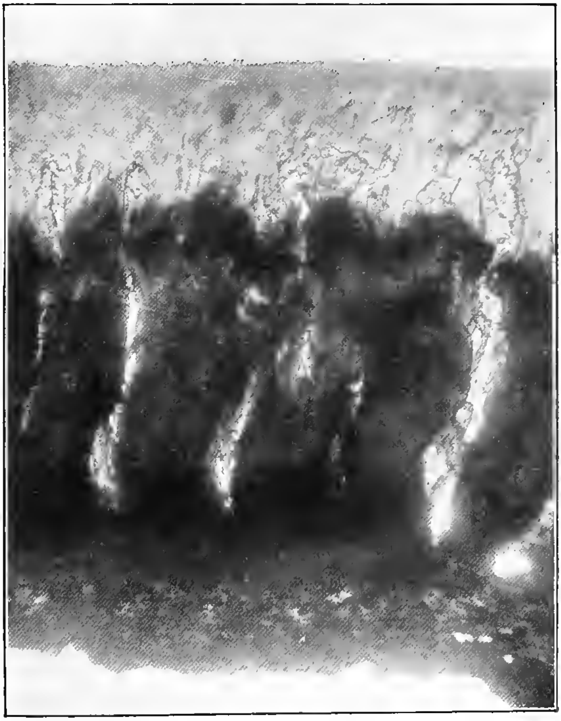
From a section cut and photo-micrograph made by the author.

PLATE 15.

A section of "colt" more highly magnified, in which further details will be noticed.

Plate 15, very highly magnified.





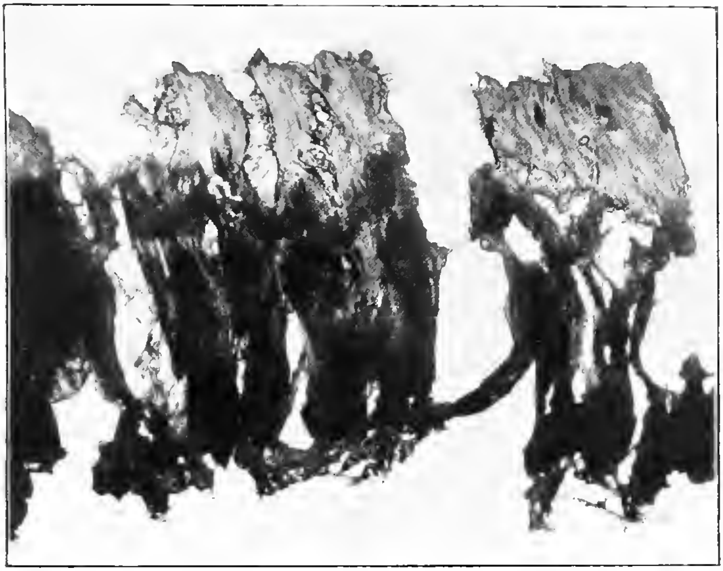


Plate 16.

This is a section made from the same sheep pelt as Plate 14.

It shows the colt columns after being teased apart. It will be noticed that the colt, where daylight has penetrated the plate, shows fine lines of fibrous tissues. The black markings, wherever they occur in Plates 14 to 16, represent the fat distribution in the pelt.

Highly magnified.

From a section cut and a photo-micrograph made by the author.

cell wall, the fat overflowing between the tissues. During this period, the general molecular forces have been nucleating until the whole mass finally becomes crystalline, a change which is further fixed by the hydrolytic processes of liming.

CHAPTER IV

MASTICATION, DIGESTION AND BLOOD CIRCULATION

> "Before the sun, while Hesperus appears,
> First let them sip from herbs the pearly tears
> Of morning dew."—VIRGIL'S *Georgic III.*

IN order thoroughly to understand and appreciate the arguments employed in this work, it is necessary to know something of the wonderful digestive system of the sheep, and his powers of masticating and assimilating the food-stuffs which go to build up the meat, skin, and wool.

Nature has intended the sheep to thrive on scanty herbage and in such places as would produce starvation in other animals of a more or less domestic character. The mouth and its contents are especially adapted for their natural functions. The lips are protected by hair, thus affording a defence from injury while eating; they are pointed and in the centre are split or cloven, enabling them to crop closer to the ground than is the case with horses and oxen. The lower jaw alone possesses teeth, the upper jaw has instead a firm fibrous pad, sufficiently tough to hold the food against the teeth. The upper cloven lip moves outwards and strokes the short grass on to the lower jaw teeth, holding it in position while the upper jaw approaches to nip and hold the grass ; meanwhile the cloven lip divides and is enabled by means of the cleft to withdraw without the hold on the grass being lost. This cycle of operations enables the sheep to subsist where other animals would starve.

The food passing into the mouth,[1] meets with an abundant flow of saliva, which fluid is secreted in three pairs of glands : the *parotid*, situate at the root of each ear ; the *submaxillary*, under the jaws ; and the *sublingual*, which lies under the tongue. From these six glands a supply of saliva is yielded in greater abundance than is the case with most animals, and is rendered necessary by the hard and fibrous nature of their food. If dry food passes into the stomach without being moistened with saliva, it will remain in the paunch in a dry condition for some period of time, causing great inconvenience.

The Organs of Digestion.—Like all the graminivorous animals, the sheep possesses that extensive digestive system which is so pre-eminent a feature in its animal economy, since it has more elaborate and difficult functions to perform than is the case with carnivorous animals whose food is taken as it were ready prepared, and is composed of similar materials to the blood itself and the flesh it is intended to nourish. Like other herbivorous animals the sheep receives its food in an unprepared state, the nourishing portion bearing a small ratio to the whole ; accordingly the amount of food consumed is much larger, and to meet these conditions the organs have to be of greater capacity, and the general arrangements for dealing with so large a bulk of totally unnecessary matter on a liberal scale. This point must not be overlooked when considering the fattening of sheep with prepared food stuffs. The food after passing through the *pharynx* proceeds to the *œsophagus*, a long tube which leads to the stomach. This tube has its power exerted from external muscles to force the food forward to the stomach or stomachs.

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[1] The following has been extracted and arranged by the author from the work of W. C. Spooner, M.R.C.V.S., "The Sheep," 1888 edition, and he desires to fully acknowledge his indebtedness.

The sheep is equipped with four stomachs ; the first stomach or *rumen*, which is considerably the largest of the four, occupies at least three-fourths of the abdomen. It is the receptacle for the hard food which has received enough mastication to enable it to pass down, but will require further rumination. The second stomach or *reticulum* is less in size but secretes mucous fluid which prepares certain portions of the still incompletely undigested food for assimilation ;—this stomach is familiar to many readers under the common name of *tripe*. The third stomach or *omasum* or *maniplus*, so called from its internal structure, possesses a peculiar formation on its walls, which consist of protruding points resembling half a crescent. The fourth stomach, or *abomasum*, is in fact the true stomach ; it secretes the powerful gastric juices which convert the food into *chyme*, that interesting substance commonly known as *rennet*, so much used in the production of cheese.

After the sheep has eaten until the first stomach is full, he feels a sense of repletion, which can only be

PLATE 17.

THE STOMACHS OF THE SHEEP.

a. The œsophagus, after it has passed the diaphragm, and is approaching the stomachs, and the funnel shape termination of it, the external coat being stripped off. When thus viewed it appears to terminate in the rumen or paunch.

b. A portion of the external layer of the spiral muscles. They are crossed below by another layer running in a contrary direction. By the united action of the two the food is forced down the gullet after either of the mastications; or returned for the second. The fibres are thickest and strongest at the termination of the tube.

c.c. Represent the two divisions of the paunch, or the first and largest stomach; and, the external or peritoneal coat being dissected off, the two layers of muscles that surround it are brought into view. They cross each other at right angles, they are very powerful, and by their united action the food is carried through the different compartments of the stomach, and every portion of it exposed in its turn to the influences of the moisture contained in, or secreted by, the stomach.

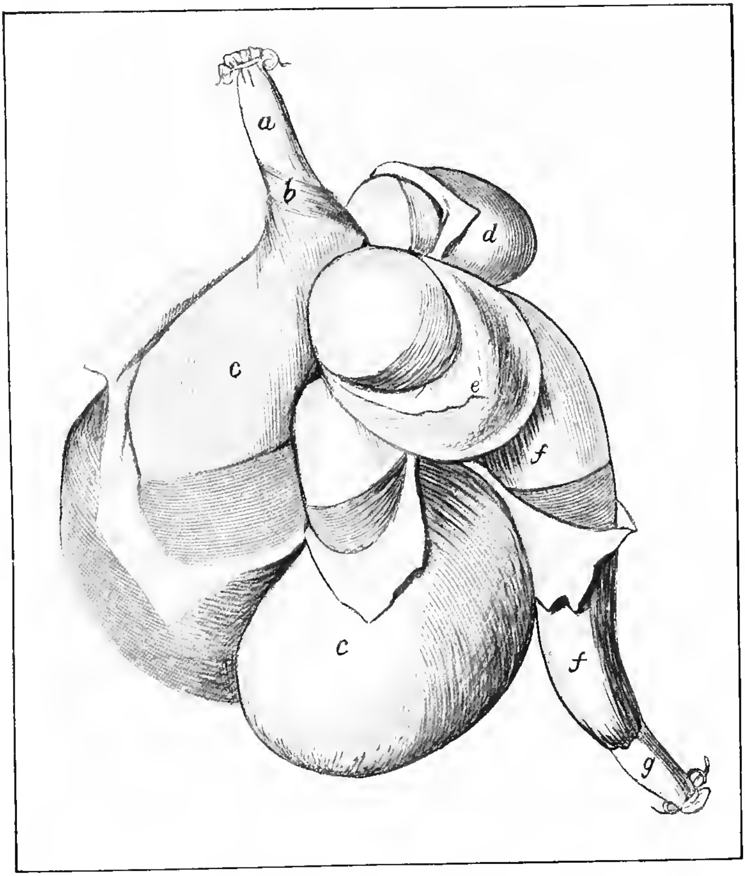
d. Represents the situation and form of the reticulum, or honeycomb, with its two layers of muscles.

e. Is the maniplus, or manyfolds, with its double muscular apparatus for the purpose of triturating the hard portions of the food which may have escaped the second mastication.

f. Is the fourth stomach, or abomasum, also with its layer of muscles. The food having been sufficiently comminuted is here converted into chyme.

g. Is the commencement of the duodenum, or first intestine.

Plate and description is taken from Youatt on "Sheep."


a
b
d
c
e
f
c
f
g

satisfied by rumination. This act, frequently spoken of as "chewing the cud," is performed in a recumbent position. If he has been eating for some hours, it has been found that the food which first passed into the mouth for "chewing the cud," is that which was eaten first, and which has received the greater treatment in the *rumen.* It will thus be seen that the muscles of the œsophagean canal have the double power of forcing the food down to the *rumen,* and of returning it to the mouth, which during the act of rumination they proceed to do. The *rumen* would appear to possess the ability of turning the food over in order that the first food partaken of may come first into the mouth.

If the food in the *rumen* is moist, such moisture is expressed by the stomach muscles and delivered direct to the second stomach, while the unmacerated dry food is returned to the mouth for further maceration. It is therefore evident that the duties of the œsophagus are more onerous than in the case of non-ruminating animals. The operation of the first stomach is, in the first place, as a storehouse for the food as it is received, and, during storage, to moisten and prepare it for further mastication. The food after being prepared by mastication is sent into the second stomach, where it is charged with juices which when assimilated are expressed by the stomach into the third stomach, and finally into the fourth stomach. Each stomach has peculiar and definite functions to perform according to the class of food eaten. As an example, the young lamb dines off milk which contains all the elements of nutrition in a much more perfect state than it exists in vegetable food, and it requires but little separation in order to fit for nutrition, so the milk passes direct into the fourth stomach. As the lamb begins to nibble the herbage, the other stomachs develop in proportion to the use to which they are put. All the stomachs are permeated with countless blood vessels, playing an important *rôle* in the process of assimilation of the food juices.

The Blood and its Circulation.—The blood is the most important fluid and plays the greatest part in all the animal economics; it stimulates the heart to action, secretes and nourishes every part of the body, furnishes heat and vitality. The blood is a living quantity, having a separate existence apart from the body, as has been demonstrated by Von Recklinghausen[1] who kept blood not only fresh, but living and growing and developing its corpuscles, after it had been removed from the body for five weeks. It must therefore be considered as the most important fluid in the system, upon the healthy condition of which everything depends for the successful production of stock. As will be seen in the chapter on cockle, the surcharging of the blood with excessive fats and the resulting drain on the skin by the wool, is responsible for the varying appearance of cockle.

The temperature of the blood in the sheep is about 100 degrees Fahrenheit, being slightly warmer in the arteries than in the veins. During sickness the temperature may rise in the case of fever or fall in the case of ague. This vital fluid in the sheep is estimated to be about *one-fifth* of the total weight of the carcase; and

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[1] "Fragments of Science." Tyndall.

PLATE 18.

A photo-micrograph of an injected section made by the late Mr. Stirling, Edinburgh, loaned to the author by Dr. Drinkwater.

This is a particularly beautiful injected section of human skin, made by the most celebrated section cutter of the last century. It shows the capillary vessels feeding the hair follicles and papillæ and extending throughout the sub-epidermal area, thus reaching the nucleated cells of the epidermis.

The sloping, thick dark lines are pieces of hair which have been cut through, except in the case of the last hair on the left, near to the grain surface. At the base of the hairs will be seen the root or bulb with the papilla in the centre, and entering same are seen the blood capillaries feeding the follicle and the root through the papilla. Surrounding the hairs and in the skin mass are zigzag fine dark lines, being blood capillaries conveying nourishment to the hair follicles. These extend to the nucleated cells of the grain, which is the wavy dark line in the upper part of the figure.

It will repay the reader to study this figure with a hand magnifying glass, when its beauties will be more fully appreciated.

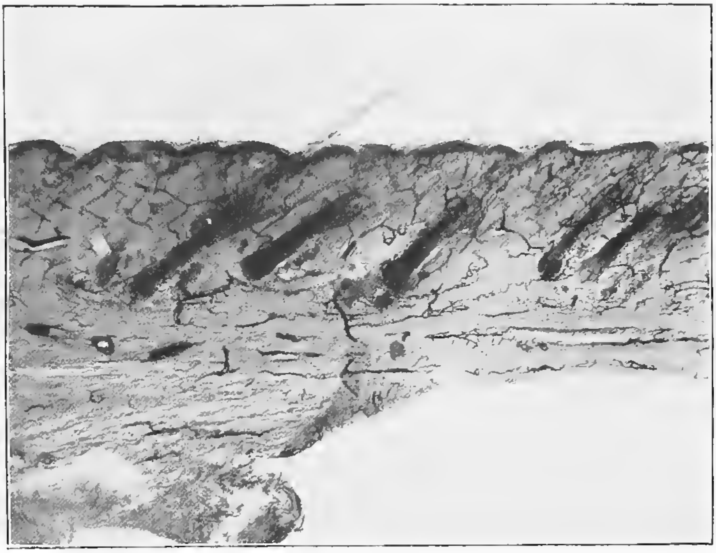
From a photo-micrograph by the author.

PLATE 19.

This is a more highly magnified photo-micrograph of a part of Plate 18. In photo-micrographing sections, there is an optimum point of enlargement, after which definition is lost. This is due to the difficulty of focussing with a high power, the several planes presented by a skin section, in this case an $\frac{1}{8}$th objective and an extended bellows of some two feet or more. However thin and fine the section may be cut the various parts or organs will assume different planes or heights and depths. Hence the lack of focus of certain parts, and the clearness of others. In this figure the blood capillaries have been focussed and may be seen without a hand glass.

This section shows the scurf or epidermeal scales being thrown off from the grain in the upper part of the photo-micrograph.

From a photo-micrograph by the author.



of this amount *three-fourths* are contained in the veins, and *one-fourth* in the arteries.

The heart is a focal point and operates as a pump to circulate the blood ; it consists of two halves or sides, called *auricles*, the right auricle receives the used up blood from all parts of the system, and passes it into the right ventricle, which, by contracting, forces the blood through the lungs, which are ramified with countless miles of minute vessels or conduits; here it is exposed to the action of the inhaled air and purified of its bluish colour and again returned to the heart in a reddened state charged with the oxygen and some nitrogen from the air, the impure air in the form of carbonic acid gas being exhaled.

This revitalised blood is received by the left auricle but not before it has received a charge of *chyle* which has been extracted from the digested food absorbed by certain small vessels called *lacteals*, and conveyed by specific channels to the heart. Such vitalised blood is conveyed to every part of the body, skin, wool, etc., as will be seen in plates 18 and 19, where, if a magnifying glass is used, the blood will be seen entering into the papilla of the hair; and in plate 20 the vessels will be seen feeding the nucleated cells of the "grain," or epidermis. The vessels conveying the blood to the outlying parts are called in the first instance. *capillary arteries*, which again terminate in what are termed *capillary veins;* so minute are these capillaries, that the finest point of the finest needle cannot be plunged into the skin without penetrating them and drawing blood.

During the passage of the blood through the body, it keeps parting with some portion of its constituents, according to the local requirements and demand, at the same time becoming charged with matter which the system desires to get rid of, in consequence it grows darker in colour in proportion to the amount of carbon with which it may be charged. After it has performed all its allotted work it is again returned through various organs to the heart for purification.

The Liver.—The Liver is essentially an organ of assimilation, secretion and excretion, and plays an important part in the manufacture and purification of the blood. It secretes *bile* and the nutritive portions of the food; it also excretes that portion of the food which would be injurious to the blood in performing its functions. One operation which it carries out, a very important one from the leather manufacturer's point of view, is the elaboration of the fatty matters, either from saccharine substances or albuminous compounds.

One of the functions of the bile is that it neutralises the acidity of the food or chyme accumulated in the stomach by means of the gastric juice, and thus prepares it for the separation of the *chyle* which may be seen on the surface of the food. The bile is alkaline and the chyme is acid. The quantity of bile secreted by the sheep during the twenty-four hours will amount to as much as 5 lbs. Besides performing the purposes to which we have referred, the bile performs other functions of equal importance; it enables the food to be assimilated, it carries away materials which would otherwise impair the blood, assists in

PLATE 20.

A highly magnified photo-micrograph from a section of human skin injected by the late Mr. Stirling, Edinburgh.

This section was injected with suitable staining in order to show the blood capillaries. In the bottom left-hand corner is a large artery, the blood is missing. The next in size, black elongated markings are similar vessels with the blood content. As the upper portion of the figure is approached, the finer irregular vessels appear extending right up to the nucleated cells of the epidermis. If the section is examined with a hand magnifying glass, or by the naked eye, the almost straight dark lines extending from a sack-like formation will appear as tubes; these are the sweat glands and ducts which terminate through apertures in the grain.

From a photo-micrograph by the author.

PLATE 21.

A very highly magnified photograph of an injected section cut by the late Mr. Stirling, Edinburgh.

It represents a horizontal section of human skin cut about the line, just above the hair bulb, and shows in the dark grey thick surrounding ring, the hair follicle, lying within which are, interlacing each other in all directions, countless blood capillaries, nourishing the hair, which is the centre mass, and in the extreme centre is seen the hair pith.

On the outside of the hair follicle, and in the skin mass, are blood capillaries, as shown by the dark irregular lines, nourishing the hair from the exterior. The dark grey spots in the skin mass are the fat lobules.

It will be realised from this and the preceding sections, how wonderful are the provisions of nature to care for even the most minute organisms, the cells of the skin. A study of these figures will assist the reader fully to appreciate the effect of what is written herein in regard to the effect of artificial feeding of sheep, etc.

From a photo-micrograph by the author.

the secretion of the *pancreas* and the chylification of the chyme, and the chyle thus formed is absorbed by the *lacteals* and carried into general circulation. During the process of chylification, a portion of the bile—the colouring matter in particular—as excrementitious matter is moved onwards with the unassimilated parts of the chymous mass and is ejected as fæculent material.

That portion of the fluid which is employed in the chylification, among other things acts on the starch of the food and converts it into sugar, ready to be taken up by the capillaries.

The liver must, therefore, be regarded as the regulator of the amount of sugar and fatty matter taken up by the blood, *any excess of which, not being required for the support of animal heat, accumulates in the various tissues of the body, and particularly the skin and wool.*

Professor Franz Lafar, in his "Technical Mycology," page 229, has the following interesting reference to the action of the enzyme juices of the stomach and intestines in man: "On issuing from the stomach—where, by the action of pepsin and hydrochloric acid secreted by the gastric glands, a more or less extensive peptonisation of the digestive albuminoids in the food has been effected, the pulpy food, now known as *chyme*, has a strongly acid reaction (equivalent to 0·1 – 0·3 per cent. of hydrochloric acid). Immediately on its arrival in the upper division of the alimentary canal (small intestine), it becomes mixed with the bile and pancreatic juice, under the influence of which the fat is emulsified and the insoluble carbohydrates (starch) are hydrolysed. Both secretions have an alkaline reaction, which, however, is not sufficiently strong to immediately neutralise the acidity of the contents of the intestine. This slightly acid nutrient medium, rich in sugar, offers a favourable field for the activity of the lactic acid and allied bacteria introduced along with the food; and, moreover, the acidity restricts the development of the competitive putrefactive bacteria. In proportion, however, as the contents of the intestine are forced onward and approach the colon, the acid reaction is neutralised by the alkaline mucus secreted by the intestinal glands. At the same time the composition of the mass has become changed, since the products of the hydrolysis of starch, which have also to some extent been converted by the aforesaid bacteria, have been absorbed into the blood-vessels. Therefore in the contents of the colon it is the (undigested and indigestible) albuminoids and bilary constituents which are decomposed by the putrefactive bacteria now coming into action, and it is here the malodorous products (indole, shatole, volatile acids, sulphuretted hydrogen, etc.), to which the intestinal contents (finally issuing from the rectum as fæces) owe their repulsive smell, are produced."

The operation of digestion is exclusively a chemical change, and, as has been shown by MacFadyean, Nencki, Sieber, Nuttall, and H. Thierfelder,[1] bacteria play no part in the process.

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[1] "Technical Mycology," by Professor Franz Lafar, Vienna.

PLATE 22.

This is an enlarged photograph of a sheep skin after tanning. A strip of tanned sheep leather was cut about half an inch wide, then laid flat upon a piece of sheet cork and cut with a razor at a very gentle angle from the flesh to the grain, in order to accentuate the length of cut for vision. At the top the grain appears as a narrow strip about half an inch wide showing the wool holes. Immediately below and about half an inch wide the true skin is seen in a slightly lighter shade, then follows about two inches of light-coloured cellular and fibrous tissuous mass, the fatty layer or stratum adiposum again, and finally at the base the true leather skin appears. In the original this layer is much thicker, but it was not possible to exhibit more within the range of the 3-inch lens employed. The line appearing across the picture in the left-hand corner is a fibre of cotton wool which had obtained access.

This section is of a Welsh Mountain Sheep, and shows how in that breed the excess of fat is absent and the skin tans a solid mass, with no looseness.

From a photo-micrograph and section by the author.

PLATE 23.

This is a similarly prepared section to Plate 22.

It is from a cross-bred sheep which had been artificially fed and fattened for the market inside ten months from birth.

Again, in the upper portion of the picture, the grain is seen, and just below, the true skin and the fatty layer appears as a fibrous mass of connective tissue, from which the fat has all been expressed. So excessive has been the forced feeding that it has permeated the true leather skin at the base, which also appears as a less fibrous mass.

The picture is sufficiently explanatory not to necessitate a further detailed description.

From a section cut by and photo-micrograph taken by the author.

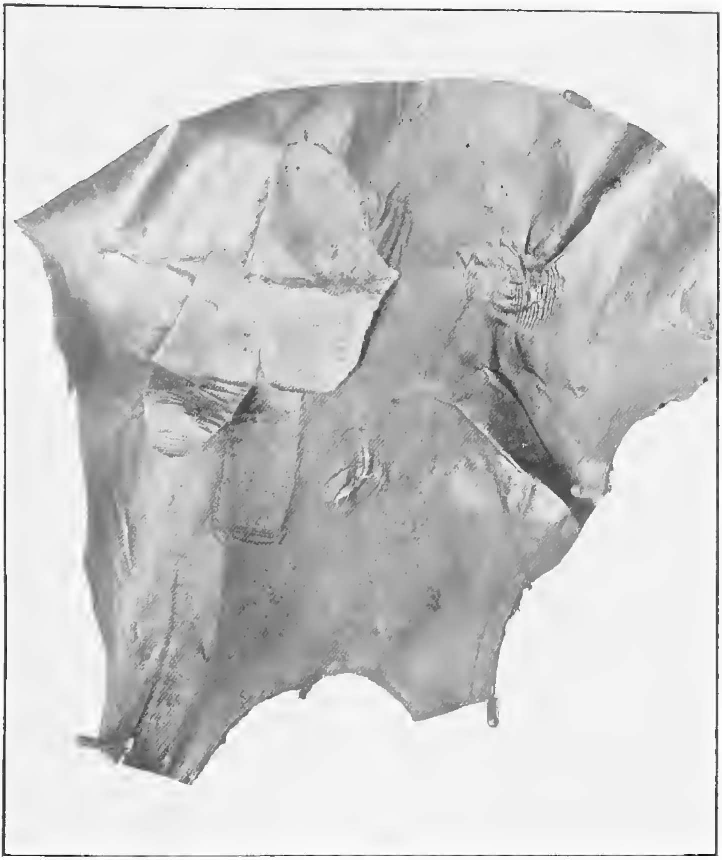

Plate 24.

A direct photograph, but reduced in size, of a flank off a sheepskin after chrome tanning, and which had been forced fed as in the case of Plate 23. After chroming the fat liquoring was excessive. When the skin was brought under the glazing machine the grain and flesh parted as shown by the stripped portions and the pinches. This illustrates how far into the hitherto non-fat parts of the skin the effect of artificial feeding will distribute the excess of fat.

From a photograph taken for the author.

In the case of the sheep with its enormously increased digestive apparatus this cycle of digestion is immeasurably augmented, and serves to explain in some degree the results obtained to-day by rapid and artificial feeding and fattening of sheep with the many specially prepared foods, which are offered for sale, as compared with the methods existing about thirty years ago of natural feed and development. The change in feeding has had most momentous consequences during the past three decades in altering the general character of the pelts; a change which has not received the attention which the seriousness of the results calls for, and the so-called improvement from the stockraiser's standpoint continues and will continue to be applied. The result is a greater accumulation of fat within the skin, with a corresponding destruction of the central layer in which the wool roots appear. This layer, originally close and fibrous, yet containing the natural accumulated fats, becomes adiposed and the finer fibrils dissolve, thus forming an excellent medium for putrefactive bacteria to thrive in.

CHAPTER V

DISEASES OR AFFLICTIONS OF THE SKINS OF SHEEP

> "In flowery springtime, when the new-dropped lamb,
> Tottering with weakness by its mother's side,
> Feels the fresh world about him, and each thorn,
> Hillock, or furrow, trips his feeble feet,—
> Oh, guard him carefully!"—DYER'S *Fleece, Book I.*

THE diseases of the sheepskin are comparatively few, but the afflictions are many; and in nearly all cases caused by insect life infesting the wool of the living animal. It is very necessary that those engaged in the sheepskin industry should become familiar with the causes which produce the destruction of the "grain" of the pelt; and, while not intending to probe very deeply into the pathology of the diseases or afflictions, it would be as well to describe those which are of the first importance, and also the effect produced in so far as it may be of interest to the leather trade.

The ailments of the body are many and are scarcely of sufficient interest to the tanner, except in the case of the "Fluke or Liver-rot" which is fully described in the next chapter; nevertheless, the bodily diseases have a serious result on the condition of the skin.

The sheep, as has been shown, possesses a very powerful digestive system, with a greater capacity than that of any other domestic animal to convert grass, roots, etc., into flesh and fat, and to extract from coarse and comparatively unnutritious fodder the nutriment existing therein in a diffused state, and this in quantities which would kill other domestic animals.

With a small brain, weak intellect, feebly developed nervous system, most of which nervous energy is absorbed by the digestive organs and weak muscular development, the sheep is unfitted under domesticity to withstand disease as compared with other animals, and when disease assails it the sheep loses condition rapidly, both in body and skin. The skin is the first to feel the effect of the attack, as it is the last to partake of the improvement. The general effect of any attack by disease on the sheep would appear to be a withdrawal of nutrient material from the skin and wool in the first instance, with a consequent suspension of growth. If the disease is not cured, the withdrawal continues and the skin loses fat, etc., becoming poor and thin. The domestic sheep is essentially an artificial production, educated in habits of inactivity and quietude, which when disturbed result in destruction of those qualities and advantages so much desired by the shepherd.

As may be imagined, the sheep is prone to maladies of the digestive organs, of a mechanical and chemical nature ; not least among which are those produced by eating the eggs of parasites which lay their eggs in the grass. Fortunately most of such eggs succumb to the strong effect of the gastric juices of the stomach.

The vascular system is feebler than that of many other animals, and the sheep being of sedentary habits, the drain upon its blood to repair the effect of muscular exertion is practically nil ; hence there is an indisposition to inflammatory disease which is increased by the great powers of assimilation possessed, nutritious food being so quickly and readily converted into flesh and fat.

Growth of Animal Tissues.—In order to make our view clear as to the causes which produce the untoward effect in the skins, it will be necessary briefly to describe the development and growth of animal tissue.

"All the animal tissues,[1] however diversified they appear, originate as collections of elementary corpuscles or cells" (which reproduce and multiply, *i.e.* they are all living and capable of reproduction of their species) "and remain, many of them, as constituent elements of the formed tissue." "An animal cell is a corpuscle of microscopic dimensions, the cells of the human body seldom exceeding $\frac{1}{300}$ of an inch in diameter, and many being as small as one-tenth of this or even less. But whether small or large, every cell consists of two distinct parts ; of the main substance of the cell, which has received the name of *protoplasm*, and of a minute vesicular structure placed near the centre of the cell, and termed the *nucleus*."

The cells receive their food from the capillary vessels, and are wonderfully endowed with the function which enables them to secrete just the requisite material from the blood to build up the individual structure for which they are specially created or in which they are interested. For example, it is a wonderful provision of nature that the cells of the mammary glands extract only those substances from the blood stream which enable the parent to feed its young, and allows those elements which are intended for the creation of other bodies or tissues to pass on to their destination. So is it with the several varieties of cells which go to build up the tissues of the skin and wool; as each cell is fed from the blood stream in the capillaries which may be seen in plates 11 to 13, any bodily disease at once withdraws from those outlying areas much of the health-giving blood in order to repair the ravages of the disease upon the internal tissues. Such blood as may reach the skin cells is thus of a poorer quality and the cells are starved and shrink in size. Further, each cell is directly connected with the nervous system, and any depression in the animal's condition at once causes the cells to lie dormant or cease production. A study of the chapter on *Fluke* will considerably help the reader to appreciate this point, that any internal disease, however caused, produces effects which imply withdrawal of blood, etc., from the skin cells and consequent reduction of their size and functions with a corresponding withering away of the size of the animal and its skin. If the disease is prolonged, the degradation of the cells proceeds until death of the cells ensues, the vitality of the animal becoming so reduced as eventually to cause its death.

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[1] Quain's "Anatomy."

The maintenance of the animal in the most perfect state of health is absolutely necessary to a sound condition of the skin, and, further, it is of the most vital importance that the following fact should be hammered home to every one engaged in the raw skin trade, viz. *that when an animal in perfect health is killed, it must not be assumed that the bodily cells die immediately, they will continue to live for a considerable time after the demise of the animal.* This fact is being made excellent use of to-day by surgeons, who remove, immediately after death, parts of the body for grafting on to the bodies of living human beings who may be minus such parts. Von Recklinghausen[1] astonished the late Mr. G. H. Lewis by showing him blood, not only fresh but living, and growing, and developing its corpuscles, after it had been three weeks, a month, and even five weeks removed from the body.

Every leather manufacturer is well aware, that he can produce the best leather from the *absolutely* fresh market hide or skin. For example, the tanner who fellmongers the local market sheepskins and tans them, always obtains better results than the manufacturer who buys his skins from a fellmonger, who, after fellmongering, collects the pelts in a so-called gathering lime; for the simple reason that, in the first instance, the manufacturer obtains the skins with the skin cells all living, reproducing and growing, whereas, in the second case, the fellmonger permits the organisms of putrefaction to kill and destroy the cell life by his obsolete methods of handling the pelts.

The prevailing methods—at least existing in the British Isles—of butchering in private abattoirs and subsequent shipping of the skins to the auction sales at some large town, with the lapse of time between killing and the return of such skins to the fellmonger, whose

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[1] "Fragments of Science."

PLATE 25.

A section of human skin cut by Dr. H. Drinkwater, F.R.S.E., showing a hair *in situ.* The hair bulb is seen in the stratum adiposum or fatty layer, and surrounded by fat cells (unstained), areolar tissue and connective fibrous tissue. The blood capillaries are not shown, this being only possible by injecting the section. On the left side of the hair an excrescence is seen, having at its base a thick dark line striating out from the hair follicle. This excrescence is the "sebaceous gland" which will be seen to empty its contents into the hair follicle at the right-hand top, at a point close to the exit of the hair follicle. The dark thick line immediately underneath the sebaceous gland is the erector pili muscle, which extends from the hair follicle to the grain, but, unfortunately, in cutting the section, it was cut through, just at the point where the sebaceous gland ends. The function of this muscle is to erect the hair, in cases of fear or sudden chill, or excessive sudden heat, by contraction, pulling at the base of the hair follicle, pushing it upward and forming the so-called "goose-flesh." While doing so, it squeezes the sebaceous gland, causing it to excrete into the hair follicle the fatty matter to seal up all ingress, and so prevent the entrance of foreign matter.

The section is highly magnified.

From a photo-micrograph by the author.

PLATE 26.

A more highly magnified photo-micrograph of the same section as Plate 25, but of another hair follicle and sebaceous gland. This figure shows more clearly the sebaceous gland emptying its contents into the hair follicle directly through a small vessel or tube. The dark upright line crossing the sebaceous gland in an upward direction is another hair which has been cut through. Underneath the sebaceous gland will be seen at the left hand a part of the erector pili muscle, which, in cutting the section, has been cut through. In the centre of the hair follicle the hair will be seen but its bulb has been cut away.

From a section cut by Dr. Drinkwater, and the photo-micrograph made by the author.

premises are invariably remote from such auction marts, are the prime evils which militate most seriously against successful production of sound leather in these Isles, an evil which is materially assisted by the increase in artificial feeding.

It is not too much to say that, in the interests of sound leather, the whole present system, so far as it concerns the ancient art of fellmongering as it prevails in the British Isles, requires very serious consideration, alteration, and amendment.

If the present system is to continue, then the butcher, in the interests of the buyer and the general public, must cure his sheepskins (and hides) with clean fine ground salt before shipment; or private slaughter houses should be forbidden, which means that the system, as it prevails on the Continent, of public abattoirs, or the American and Colonial system of slaughter and subsequent fellmongering by the abattoir authorities, will prevail. The latter is not to-day practicable in the British Isles, but the enforcement of some form of cure which will preserve the woolskin and its living cells in a healthy condition when received by the fellmonger and whilst in the hands of the latter also, is within the realms of practical politics and should be very carefully considered by the Federations interested, in their own interests and that of Public Health. The two points for attention are :—Effective curing by the butcher and efficient fellmongering in order to prevent, in both cases, the activity of putrefactive organisms.

A sheep, unlike the ox or horse, is by habit ill adapted for work; this indisposition to work is increased by the system of breeding and feeding adopted, with inculcated habits of inactivity and quietude artificially induced. Exposed to all weathers, changes of climate and temperature, with a digestive apparatus, consisting as it does of complex parts for the elaboration of the food, such as does not exist in many other animals, there need be little surprise if the immediate effect of any serious ailment upon the system of the sheep is to cause it to cease to fatten and pine away. It is an old saying that it does not pay to doctor a sheep, better hurry it away to a butcher before it loses too much weight. The consequences are only too apparent to the tanner in the character of the pelt and grain.

The afflictions prevailing among sheep are numerous, but one and all have a direct influence upon the pelt. The worst enemy is the fly or parasite. Many of the parasites belong to the fly class, their wings having disappeared in the process of time by continued inaction. The question of flies as a means of carrying disease is being studied by many eminent entomologists,[1] and there remains no longer any doubt that these insects must be ranked among man's greatest enemies. Among sheep the following diseases are produced by parasites: Sturdy or giddiness, louping-ill, scab, fly-blow, and, in a minor degree, injuries to the grain from ticks.

Sheep-scab.—This disease is a peculiarly distressing one among sheep, and is not confined to any one country, nor is it a modern disease. Ovid, speaking of a pestilence that prevailed in the Island of Ægina 1300 B.C., describes the falling off of wool from the sheep and their gradual wasting away:—

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[1] See the various Blue-books on "Flies as carriers of disease," issued by the Local Government Board. Also *Journal of Hygiene*, vol. 12, No. 3, pp. 290 to 319.

> "Lanigeris gregibus balatus dantibus aegros,
> Sponte sua lanaeque cadunt et corpora tabent."
> *Metamorph.*, lib. vii.

Livy refers to a disease, *scabius*, so prevalent among cattle and sheep, in the neighbourhood of Rome, in the year 424 B.C.

Virgil also graphically describes the mange or scab in his "Georgics."

Howell the Good, King of Wales, A.D. 940, promulgated the first laws connected with the diseases of animals.[1] Among the many excellent laws, all of which are deserving of more space than we can afford, may be found the following interesting reference to sheep-scab: "The seller of sheep ought to be liable for warranty in the case of scab from the Feast of All Saints to the Kalends of April," that is, from the 1st of November to the 1st of April (five months). An observation which justifies the orders issued by the Board of Agriculture in regard to this evil. Further, Howell the Good says: "The buyer shall not put them (the sheep held on warranty) where sheep which have had scab have been, until (unless ?) the place has been isolated for seven years."

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[1] The Laws of King Howell the Good of Wales, who lived in the tenth century, have been translated and published into English from the ancient Welsh and Latin, and may be purchased at second-hand bookstalls.

Sheep-scab has stood out prominently for thousands of years as a most formidable skin affliction among sheep by its persistence and great difficulty in eradication.

The effect of sheep-scab on the pelt varies with the virulence and age of the attack. This mischief, as it appears to the observer, is at first seen by the wool becoming detached from the body, especially the part attacked and falling off. If the affected part is examined with the naked eye the surface of the skin will be seen to be covered with an eruption, at first slight, but, as the age of the attack is increased, sores appear, and the disease, unless attended to, will gradually spread over the whole body.

If the affected part be examined with a hand magnifying glass a number of little insects will be observed moving in and out among the wool fibres. These are a species of mite or acarus, known scientifically as *Dermatodectes ovis* or *Psoroptes communis.* The disease belongs rather to the parasitic order than to the purely contagious, although it is essentially a highly-contagious disease. Leaflet 61 of the Board of Agriculture[1] may be quoted in full: "One of the first symptoms apparent in the sheep that has contracted the scab, is the restlessness, combined with a desire to bite the affected part, or to rub against posts, fences, hurdles, or even other members of the flock. This restlessness is the result of irritation produced by the mites pricking the skin of the sheep in their endeavour to obtain food. The constant rubbing of the sheep to allay irritation causes injury to the skin, which is followed by an exudation of serum, and the formation of crusts or scabs, under the edge of which the parasites and their ova are found.

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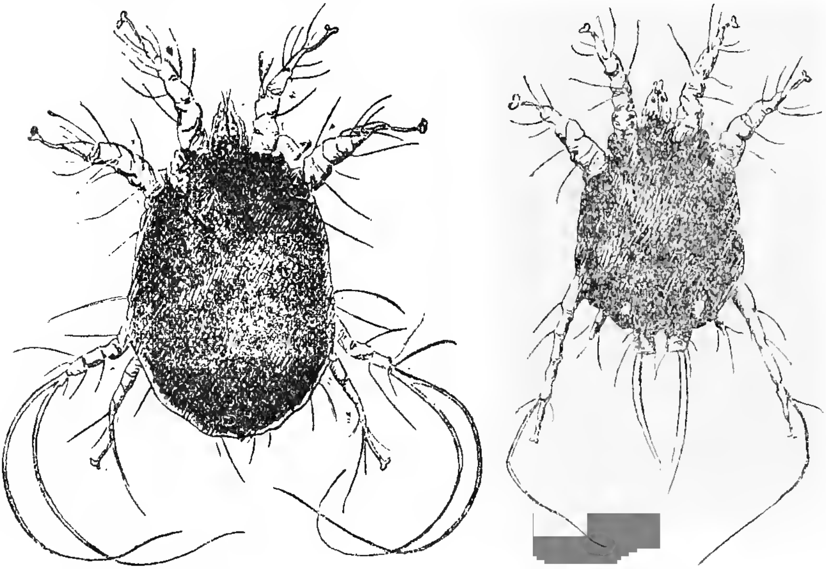
[1] All the leaflets may be obtained from the Board of Agriculture, Whitehall, London, on application by post.

"As the mites increase in number they move from the scabbed to the more healthy parts of the skin and thus extend the area of the diseased parts. The injury to the skin is followed by the shedding of the wool, and the fleece becomes broken and tufted, or matted together, giving the animal a ragged appearance. Even when the wool does not detach itself from the skin, it assumes a dead-white bleached appearance.

"The most convenient method of examining a piece of wool or crust taken from a sheep suspected of scab, is to spread it out upon a dark surface, and place it in the sun or any other warm position. If it be a case of scab the mites will be seen as small specks moving about on the wool or perhaps on the surface beneath it. These moving objects should be examined with a pocket lens or microscope of low power, when the parasite and their eggs will present a characteristic appearance.

"The mature scab acarus measures from $\frac{1}{40}$ to $\frac{1}{50}$ of an inch in length, the female being somewhat larger than the male; each has four pairs of legs. Each foot of the first three pairs of legs of the male is furnished with a sucker-disc; but in the case of the female this disc is on the third pair of feet and is replaced by long hairs. *The Egg* is about $\frac{1}{125}$ of an inch long. The *immature mites or larvæ* have only three pairs of legs.

"After the parasite has been transferred from the diseased to the healthy sheep, the female lays her eggs and dies. The eggs under favourable circumstances are hatched out in about seven days, and the young female parasites, after undergoing various stages in their development, arrive at maturity in about two weeks, when they, in their turn, proceed to lay eggs."



Female. Male.

Sheep-Scab Mites (*Psoroptes communis*). Female × 65.
Male, copulatory suckers extended, × 65.

The full life cycle, as detailed in the leaflet referred to, is of great interest, but doubts have been raised whether it discloses the complete life cycle of the acarus. It is suggested that the acarus may possibly be found to possess oviparous as well as viviparous faculties as some other flies (the acarus is but a degenerated fly).

The appearance of scab on the denuded pelt will vary with the virulence of the attack, and, in its early stages, according to the class and growth of wool. In the incipient stages with "lock wool," the injury to the grain will bear a close resemblance to "ringworm," an unknown disease among sheep, but with which it has been confounded. On close-woolled sheep, it will follow the lines of break in the wool; *i.e.* it invariably, in the first instance, proceeds along the lines of least resistance in order to obtain the initial foothold, and in these cases, the markings will resemble a chess-board, but the squares are somewhat irregular in pattern and size. Once having accomplished the hold on the skin, the evil is very difficult to eradicate and cannot be removed without leaving the marks behind on the glassy surface of the grain. If the attack is not dealt with promptly, the evil extends and becomes a running sore, gradually spreading over the sound portions of the skin.

The ancient and modern method of extermination of scab is by means of what are called "sheep-dips." These dips are compounded of different materials: Carbolic acid, tar oils, tar acids, resins, arsenic, soda, sulphur, fat, gelatine, tobacco, lime, etc. Most of the proprietary dips are known as "arsenical" or "carbolic."

Against the employment of the approved proprietary dips, when used according to instructions, I am not aware that any objection can be urged by the tanner, in so far as the effect of such dips may bear upon the value of the pelt, although it is admitted that the dips vary in their results and efficiency on all points.

The Government of New Zealand have for years had very stringent orders in force regarding dipping, without regard to any special dip, leaving it to the stockraiser to eradicate the scab or prevent its appearance by systematic and regular dipping under stringent inspection, with the result, they claim, they have no sheep-scab in those islands. From an inspection of many thousands of dozens of New Zealand pickled pelts and from inquiries made, I have never seen nor have I heard of injuries being caused by dips as carried on in that country.

In Great Britain, the home of most of the proprietary dips, the case is different. During recent years there has been a recrudescence of sheep-scab in these islands and sheep-dipping orders have been enforced, but not on the same lines as in other countries. I am satisfied that the cause of injuries to be seen in the skins of sheep after treatment with one or other of the dips, is due entirely to the use of non-approved dips, or the misuse of approved dips by stockraisers in their nervous anxiety to eradicate the disease regardless of consequences to the pelt and pain and suffering to the sheep.

The arsenical dips are strongly alkaline and the carbolic dips are strongly acid. The first has a corrosive action and the latter a peculiar tanning effect which may blister. When a shepherd discovers that a sheep or some sheep have become infected with the scab, he has been known to take strong measures to eradicate the evil by applying the dip in a concentrated form, by pouring it over the affected part; as it runs down the body, a wound is created wherever it touches, and with the tender skins produced by the act of forced feeding, the injury is accentuated. This phase of the evil has given rise among certain fellmongers to the idea that a new disease had appeared. In the case of strongly alkaline dips, the effect on the super-fatted skins produced by artificial feeding is not far to seek. The skin readily absorbs the alkaline solution which combines with the fats, causing festering cracks of irregular circular shape, around which the grain breaks owing to accumulation of pus. The results of this vile treatment soon become apparent to the owner and he sends the sheep to the butcher, and so the skin reaches the fellmonger and subsequently the tanner in wretched condition.

Other forms of the evil arising from the use of too strong alkaline dips in the dipping tank, especially on artificially-fed stock, may be seen particularly in the tanned skin, resembling over-liming of the grain in patches. These are particularly noticeable in sumach-tanned stock, being sometimes a reddish brown, or corroded or weak on the grain. The lines of formation do not always follow one and the same pattern, and may be fairly compared with what is termed "mapping."

The carbolic dips produce a different injury when used too strong in the dipping tank. It is especially noticeable when the dips are prepared from crude tar products. Generally, the injury resembles "cockle," inasmuch as the appearance after tanning is a series of eruptions not unlike "cockle" in appearance, and usually in circular patches.

During the hearing of evidence by the Departmental

Committee on sheep-dips and dipping,[1] Mr. A. H. Berry, F.R.C.V.S., gave some interesting evidence; when answering questions upon this point, he said:—"Some dips were more decidedly corrosive in their chemical action than others, and it would appear undesirable to dip sheep in too strong or too crude dips when less violent dips will attain the end. Sheep cannot remain so long in the more corrosive dips without producing ill effects, both on the skin and on the health of the sheep. The skin becomes parched, very hard, and peels off, and I have seen occasional cases where the *necrosis had penetrated to the muscle.* The crude carbolic dips are very irritating. The more refinement in the preparation of the dip the less injurious effect it has on the skin." Mr. Berry further expressed the opinion that personally he did not consider it advisable to employ the more poisonous dip compounds under the following conditions: (1) In extensive cases of scab. (2) Open sores or wounds. (3) When scab has been recently removed. (4) Immediately after shearing. (5) Young lambs. (6) Sheep in low condition. (7) When loss of wool is extensive. (8) Ewes with lamb by their side.

"I have no hesitation in saying that *periodic and suitable dipping carried out under proper directions and control have a decidedly beneficial effect both on the health of the sheep and the condition of the wool*, and in my opinion it is necessary to dip for the prevention or cure of the following: (1) Acari. (2) Lice. (3) Keds.

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[1] Minutes of evidence taken before the Departmental Committee on the Dipping and Treatment of Sheep, 1904.

(4) Ticks. (5) Maggots. (6) To cleanse the wool and skin. (7) Indirectly to improve the quality of the wool by diminishing or removing the desire on the part of the sheep to rub or bite, thereby destroying the texture of the wool. (8) To assist in the improvement of the health and condition generally." To those conditions every tanner can subscribe and give his support in the interests of the trade.

Mr. Berry was asked, "As the results of your own observations, if you were asked, which, in your judgment, having regard to the whole circumstances, was the most efficient dip that had been tested, what would your answer be?"

A. "The dip I should employ myself would be the tobacco dip or the prepared carbolic dip."

Q. "Why do you give preference to these dips as against all the other dips that have been suggested?"

A. "Because they are so readily and easily mixed with water, because *they produce only a minimum of irritation* to the sheep, and for practical purposes they are harmless."

In the author's opinion, the tanning trade should support Mr. Berry's views, particularly under the altered conditions of feeding in the British Isles. If Mr. Berry's advice prevailed, there would be little complaint among tanners in regard to the abuse of the other proprietary dips in the hands of unskilled operators.

Sheep-dipping is performed by immersing the sheep for a space of about two minutes in a suitable tank, which contains the proprietary mixture of sheep-dip.

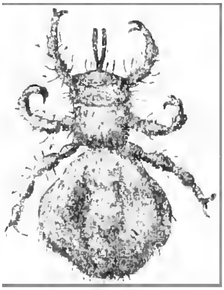
In view of the opinions expressed by several witnesses in regard to the efficacy of sulphur as a dip, the author believes that such a dip might not be without its advantages, and may be made by immersing the sheep in a bath of sodium-hyposulphite of five to ten per cent. strength for a minute or two, and then running them through a bath of an organic acid solution of half per cent. strength, which would decompose the sulphur upon the wool and skin; the evolution of sulphurous acid gas would act as an excellent disinfectant. Such a dip would be perfectly safe, even in inexperienced hands, and the materials are so cheap and readily available as to be within the reach of all.

When sheep-scab exists, it is most prevalent during the months of December, January, and February. The outbreaks are reduced by 60 to 75 per cent. during the following three months, being almost extinct in July. The injury to the pelts due to sheep dipping appears during the second half of the year, while the injuries due to scab are most noticeable during the first six months.

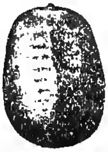
The whole question of sheep-scab continues to engage the close attention of experts connected with the Board of Agriculture and allied Institutions, and we may rest assured, that after the excellent reception accorded to the Deputation of the Allied Trades Committee by the President of the Board of Agriculture in 1910, when the views of all the trades affected were ably expounded, the time is not far distant when some improved method will be devised to eradicate this and possibly other diseases from our flocks.

Sheep Keds and Sheep Ticks.—The reader will do well to realise the difference between Keds and Ticks. They are not synonymous terms, as generally thought, and a proper appreciation of the difference will prevent the continued misuse of them.

The Ked.[1]—The Board of Agriculture leaflet 145 says: "*The Ked* (*Melophagus ovinis*). This pest, often erroneously termed 'the tick,' is probably the most widely distributed of the parasites which attack the sheep. It is a member of the same order (*Diptera*) that contains the house fly, but is wingless. It is about ¼ inch in length, has a compressed leathery body, brown-grey in colour, and covered with short hairs. The Ked does not lay eggs; these are hatched in the body of the parent insect and the maggot is nourished there. When the maggot is deposited development is so far advanced that it becomes a pupa under cover of the puparium. The brown pupal cases (*puparia*) may be found at the base of the wool fibres. Reproduction is slow, each female producing about three to five pupæ at intervals of a few days, after which it dies. Keds are



SHEEP KED
(*Melophagus ovinus*).



PUPARIUM OF KED.

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[1] See Departmental Committee's Report on Sheep-dipping.

for the most part spread by contact of one sheep with another. The mature creatures suck the blood of the sheep and cause great irritation and loss of condition.

Fellmongers are very familiar with the pest, but they invariably call it a " tick."

The Sheep Tick.—"The sheep tick (*Ixodes reduvius*) is not a true insect, but belongs to the *Ixodidæ*, a family of the order *Acarina.* On hatching from the egg, ticks bear only three pairs of legs, but when mature they have four pairs. (True insects in the mature state have only three pairs of legs.) The eggs are laid in large numbers amongst damp herbage; the larvæ, on hatching, attach themselves to sheep, and, after feeding, fall to the ground and moult, after which they become *nymphæ.* Again they reach the sheep and after feeding a short time, fall away and moult a second time, becoming adults. Once more they feed on the sheep as adults, and after gorging themselves with the blood the females tumble to the ground for egg laying. When fasting they are flat, and move with ease, but the body of the female is capable of great distension

Sheep Tick (young state).
(*Ixodes reduvius.*)

Sheep Ticks (distended).
(*Hæmaphysalis Punctata.*)

and is much larger when gorged with blood. Ticks begin to be found on sheep about March, but disappear towards autumn. They are notably common on the hill pastures of the Border districts and the Western Highlands, though they occur in other districts.

The injury these insects cause to the grains of sheepskins is probably better appreciated by those tanners who buy East Indian tanned sheepskins, especially during that period of the year known as the "ticky season." The effect of their blood sucking is to cause a minute aperture to be made in the glassy surface of the grain in order to reach the blood capillaries, inflammation locally ensues which destroys the glassy surface for some distance around the puncture.

Lice.—These insects are too well known for detailed description; they infect sheep by cutting the wool and causing itching, irritation, and unrest, doing considerable damage to the grain of the pelt. The head is large and broad, the body compressed and wingless. The louse is chiefly found on young lambs and on animals in poor condition. The injury to the grain is comparable with that produced by the Tick.

Fly Blow.—Every one who has experience of sheep pelts knows only too well of the sad ravages caused by this distressing evil. The effect is only too clearly seen in the terrible eruptions and scars on the grain side, often extending right through the skin to the flesh side. It would appear that there is still a great deal to be discovered in regard to the life cycle of the flies which are the cause of this mischief, and the subject requires much further study. Some evidence was given before the Departmental Committee on Sheep-dipping, but the results were inconclusive, inasmuch as opinions were expressed that the fly varied according to the altitude and locality. The fly commences its depredations about May in Great Britain by depositing its eggs upon the backs of the longer woolled sheep in preference to the shorter woolled lambs, but, after shearing, they frequently forsake the shorn sheep and infect the longer wool of the lambs. The act of depositing the eggs is termed by the shepherds "striking," and the flies strike with such sudden unexpectedness that it is not always easy for a shepherd to keep pace with his work of searching out the "struck" sheep. A shepherd may pass the entire flock as sound in the morning, only to find that a few hours later the fly has struck a good many of them. The difficulty, under such conditions, of shepherding sheep roaming upon the mountains is very great and at times full of anxiety. The fly deposits the eggs as low down in the wool as it can reach, often on the skin itself. The warmth of the skin and wool covering quickly hatches out the eggs and the larvæ burrow into the skin, causing excruciating pain, and unless treated, often terminating in the death of the animal. A death due to the sheep being eaten up by maggots while alive! All experienced shepherds know by the attitude assumed by the sheep when the fly has struck, and any casual observer will notice when the maggot stage has been reached by the shedding of the wool from the affected part, and the constant rubbing of the sheep against any suitable obstacle.

Fly blow is due to the sheep maggot fly (*Lucilia sericata*) of which there are probably several varieties ; at least two are known, viz.[1] "the *Green-bottles* (*Lucilia*) and *Blue-bottles* (*Calliphora*), two genera belonging to the *Muscidæ,* an important family of the two-winged flies. One of the green-bottle flies (*Lucilia sericata*) is a very prevalent cause of maggots on sheep, which, when attacked, show the following symptoms :—

(1) Matting together of the wool fibres.

(2) A continual wagging of the tail.

(3) Rubbing and biting by the sheep in their efforts to allay the irritation caused by the maggots.

(4) Much inflammation.

(5) Oozing from the sores of an evil-smelling sticky fluid.

(6) Discoloration of the wool, which falls out, and in bad cases does not grow again.

(7) Rapid loss of condition.

Description of Lucilia in Different Stages.—"*L. sericata* is a bright shining green or blue-green fly, about one-third of an inch long, and about seven-eighths of an inch in spread of wing. The fly, when examined with a lens, is seen to be covered with dark bristles, the arrangement of these bristles being used as an aid in distinguishing this and allied species.

"The *eggs* are yellowish-white, and measure about one-sixteenth of an inch in length.

"The *larva* is a legless maggot, capable, however,

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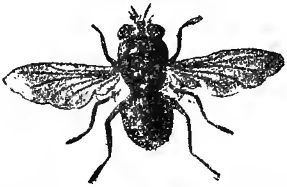
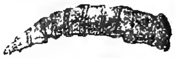
[1] See Departmental Committee's Report on Sheep-dipping and Board of Agriculture Leaflets.

of an active crawling movement. It measures, when full grown, up to half an inch or more in length; the head end is pointed and provided with two mouth hooks; the hind end is blunt with tubercles round its margin and two plates carrying the spiracles on its flat surface. Examination, with a good lens, of the first segment behind the head shows the spiracle to be fan-shaped, and to bear ten little prominences. Professor Carpenter points out that a blue-bottle maggot would show in the same situation thirteen prominences.



The Sheep Maggot Fly (*Lucilia sericata*).
Fly, twice natural size.

Pupa Case showing place of exit of Fly.



Maggot, magnified.

"The *pupa-cases* are brown and rounded or barrel-shaped, and the fly when ready issues by a hole at one end."

Life History.—"The female fly is capable of laying as many as 500 eggs and fixes these to the wool in clusters of twenty or more. These eggs may hatch in twenty-four hours, the resulting maggots feeding at first externally and later boring into the skin and flesh. In a fortnight they may be full grown, when they drop away from the sheep and become pupæ under cover of the barrel-shaped cases. In certain experiments which have been carried out, the flies issued in from less than a fortnight to over a fortnight, according to temperature and other conditions.

"An attack is worse on lambs than on old sheep, and the flies are found at work from May onwards until the autumn. Moist, warm, muggy weather, or warm sunshine after showers favours the fly. (The author has investigated the statement regarding the attack being worse on lambs, and he can speak from his own observation extending over thirty-five years, in handling many millions of lamb skins, that lambs are rarely affected; buyers of lamb pelts will also bear out this assertion. The sheep that appear to be most afflicted are those of one year and upwards, and particularly mountain sheep.)"

Loss.—Direct loss by death is infrequent where careful oversight by the shepherds is possible, such loss being most likely on hill pastures. Unfortunately, for some reason, maggots are now found at much higher elevations than formerly. Indirect loss is heavy owing to the disturbance to the flock caused by the frequent hunting and collecting. "Struck" sheep also thrive badly and are depreciated in value from this and partly on account of disfiguration.

Lydekker states that the *L. silverium* fly is also responsible for causing fly blow.

Wens, Clyers or Crewels.—Large and small lumps of fatty accumulations, round and protruding from under the grain, are familiar sights to members of the sheepskin industry. On cutting open one of these lumps there appears to be a mass of fat-like substance, which, after the liming operation, is white and solid. This is a specific disease known to science as *Actinomycosis*, a class of infective granulomata. It is wide spread and attacks most animals, including man. Bollinger and others have fully investigated it, and record it as a fungus growth which invades various portions of the anatomy, and at one period was thought to have some connection with tubercle trouble. The fungus may gain access in several ways to the body, either by the food or by inhalation. So far as its origin is known, it is supposed to be a fungus growth of certain grasses, especially on the awns. Dr. Crookshank says in his work on Bacteriology of Infective Diseases:[1] "The *skin and subcutaneous tissues* are a favourite seat of this disease, producing the so-called wens or clyers so commonly seen in the fen country. A wen is first recognised by a small tumour, the size of a marble or walnut, which increases in size sometimes with great rapidity, and breaks down and discharges its muco-purulent contents through the inflamed and ulcerated skin; or it may go on increasing, and form a large compact growth of about the size of a child's head. These growths, when excised, hardened and cut, have a characteristic honeycombed appearance, produced by the interlacing bands of fibrous tissue, which form a spongy structure, from whose interstices the fungus tufts and thick yellowish pus have for the most part dropped out.

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[1] Professor Crookshank, in his book on "The Bacteriology of Infective Diseases," has an interesting chapter (XXX.) on Actinomycosis, with illustrations.

Other and Minor Ailments.—There are other ailments which affect the skin, but they are so rare as scarcely to be worth attention, but damage to the grain resulting from brambles, thorns, barbed-wire fencing, burrs, etc., are only too apparent to all manufacturers. Sheepshearers are responsible for considerable injury to the grain, which is not confined, as is generally supposed, to the old-fashioned shears, since the modern machine shearer is responsible for considerable damage, which is not always visible until the wool has been taken off.

Tar Branding.—The applying of some form of identification by means of letters or marks of any description to the sheep is a necessity, and the common method is to use hot tar. In some cases the tar is replaced by one of the many excellent colouring dyes offered on the market. The dye is of such a character as not to wash out easily while exposed to the elements, but is easily removed by the wool scourer. The use of tar is of ancient date, and is most injurious to the wool and causes serious damage to the grain under certain conditions. Tar branding is usually performed after the sheep has been shorn and while the wool is short. The modes of procedure are various but the general and prevailing method is to use a hot iron with the owner's initials or private mark cut out deeply. In practice, this iron rests in the boiling tar pot, from which it is taken hot and pressed firmly on to the part of the sheep's anatomy to be marked. A pad of wet cloth, well saturated with cold water, is sometimes dabbed on the brand immediately afterwards to cool the tar, and so reduce the inflammation caused, and, if well done, little injury is done to the pelt, but unfortunately the iron is sometimes too hot and the damp cloth is omitted, when the skin is frequently burnt right through to the flesh. If a hot iron is not used, a brush is substituted, but the effect is often the same. Another cruel method which still prevails is to burn the owner's initials into the sheep's nose or on the face.

These cruel and inhuman practices are permitted in this fair Island of Great Britain, which boasts of societies for the prevention of cruelties to all living beings. I am not aware of tar branding being in vogue in supposedly less enlightened countries. Tar branding, however performed, entails great suffering, permanent damage to the pelt, and serious loss to the wool buyer. The practice is indefensible, and should be prohibited.

In bringing this chapter to a close, I am not unmindful of its shortcomings, and cannot claim to have more than opened the subject which is of vital importance to the industry of sheepskin tanning. Nevertheless, I trust enough has been said to attract a wider circle of observers and thinkers, especially among those engaged in the trade (because it is they who alone see the full effect of such diseases on the animals' skins), to increased study of the depreciations in the character and quality of pelts.

It is only by close study and recording of each defect, and by constant observation on the part of a widely distributed body of students, that light can be thrown on the causes—frequently obscure—of the blemishes which are the source of much anxiety to the leather dresser. The defects referred to are not decreased by the many changes which have been introduced in the breeding of sheep during the past few decades, but much may be done to meet or remedy the evils, if the causes are thoroughly appreciated and such remedies applied as may be devised during the process of manufacture. The evils will not decrease as time goes on, hence it is of supreme importance that the study and record should be as widely extended as possible. Some few years ago the sheepskin industry experienced no difficulty in obtaining at least 75 per cent. of best quality grain skins on the finished leather table, whereas to-day 10 to 15 per cent. represents a fair average.

The remedy would appear to rest along the lines suggested and the recognition of the skin (pelt) as no longer a *by-product, but a product* which has a value to the producer, and which, after flaying, is a living force, full of life and health, and must not be allowed to be killed by the intervention of the organisms of putrefaction. A fuller realisation of the importance of disease in the living animal, as a prime factor in the reduction of the product value, is also necessary.

CHAPTER VI

THE FLUKE OR LIVER-ROT

> "Nor of halt,
> Hydropic tumours, nor of rot, complain ;
> Evils deformed and foul ; nor with hoarse cough
> Disturb the music of the pastoral pipe ;
> But crowding to the note, with silence, soft,
> The close-woven carpet graze."—DYER'S *Fleece*, *Book I.*

THIS disease, although not essentially a skin disease, has a serious bearing on the skin. As it is constantly with us, and as the elucidation of the life cycle has been so completely and interestingly worked out, a whole chapter is devoted to a description and treatment of the disease.

Fluke is not confined to any one country and its existence has been known since the dawn of history, a faithful account having been given by Hippocrates. It appears periodically with great virulence, the last serious epidemic being in 1879, and is well remembered by many engaged in the industry. During an epidemic, the death rate is appalling and its effect upon the skin is the same as upon the body, viz. a gradual decrease of size.

Sheepskin tanners will have noticed among their deliveries of pelts, especially during wet seasons and from certain districts where rain is copious, a number of small-sized skins seldom exceeding fifteen to eighteen inches square, tight in texture, thin in substance, with very fine tough drawn grain, which possess all the adornments of the full-grown sheep, but are frequently classed as "dropped lambs." These are skins which are invariably off animals which have been infected with this disease. Although often classed as dropped or slink skins, it will be noticed by comparison that they differ materially in strength and form of grain.

The life cycle of this mysterious disease remained a closed chapter until Professor A. P. Thomas published his most interesting research in 1883. As this work is of intense interest to the industry, I am enabled, by the kind permission of the Royal Agricultural Society of England, to publish the whole of Professor Thomas's paper with the original illustrations.

"**The Natural History of the Liver-fluke and the Prevention of Rot.**[1]—Liver-rot, although so destructive a disease, is a preventible one.

"The object of the present paper is to give a popular account of the results of a research into the natural history of the parasite which causes the liver-rot of the sheep and a number of other animals. This research, which has now been completed, was undertaken by me on behalf of the Royal Agricultural Society of England in June, 1880; and the progress of the investigation has been already reported in two papers[2] contributed to the 'Journal' of the Society. A short account of the completed research appeared in 'Nature' for October 19th, 1882, and a detailed account intended for scientific readers was published in the 'Quarterly Journal of Microscopical Science' for January, 1883. To this last-named paper I may refer any reader who desires to learn the details of the development of the liver-fluke. The present paper is only intended to give the outlines of the life-history of the fluke in such a way as to enable the farmer and the general reader interested in agricultural matters to understand how the parasite is propagated through successive generations, how the sheep incurs the disease by taking in the young fluke with its food, and, lastly, the various methods of preventing the spread of so destructive a disease. Technical terms will, therefore, be purposely avoided.

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[1] A complete historical account may be read in the brochure, "Liver-rot in Sheep," published by the Board of Agriculture, price sixpence.

[2] "Report of Experiments on the Development of the Liver-fluke," vol. xvii., 1881, April, p. 1; Second Report, vol. xviii., 1882, Oct., p. 439.

"For the sake of convenience the subject is divided into the following parts :—

"I.—Nature of the Disease.
"II.—Life-history of the Liver-fluke.
"III.—Prevention of the Rot.

"PART I.—NATURE OF THE DISEASE.

"The Rot, liver-rot, fluke-disease, coathe, or bane, are all names given to one and the same disease. It is sometimes known as the sheep-rot, since amongst our domesticated animals the sheep is by far the most frequent victim. Very many other animals that eat grass or herbs are, however, subject to the disease, including cattle, deer, horses, pigs, rabbits, hares, kangaroos, camels, etc.; and even man himself is occasionally attacked.

"Liver-rot has been known and dreaded from very early times; it was so well known in Shakspeare's day that an allusion to it occurs in his writings. It is unnecessary for me to enter here into a history of the disease; for this I may refer to Professor Simonds's paper.[1]

"Many theories have been suggested as to the cause of the disease, several of them being very far from the truth. It is really a parasitic disease, and is caused by the presence, in the bile-ducts of the liver of the diseased animal, of large numbers of a flat worm, known as the liver-fluke (called by zoologists *Fasciola hepatica*, or less correctly, *Distoma hepaticum*). The liver-fluke has the shape of a privet-leaf, or of a small sole; it is pale brown or of a flesh-colour, and is about an inch or an inch and a third in length, and in breadth about half its own length. At one end is a narrower projecting portion, which may be compared to the short thick stem of the leaf; this is the head part, and at its tip is placed the mouth in the middle of a small sucker or sucking-cup, by which the fluke can attach itself. At the point where the head joins the flat body and on the lower surface is a second sucker—the ventral sucker.

"The liver-rot caused by these flukes is always common in certain districts of England, and it has been estimated that the average annual loss of sheep in the United Kingdom amounts to no less than 1,000,000.

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[1] See p. 9.

The rot also occurs almost all over the world, extending to Egypt, Australia, Tasmania, and North and South America, and is nearly or sometimes quite as destructive in these countries as in the British Isles. Professor Leuckart estimates the average loss per annum in Central Europe alone at 1,000,000 head.

"But a series of wet seasons always increases the prevalence of the disease. At such times it spreads to districts which are ordinarily quite free from it. The year 1879 was one of a succession of wet seasons, and the losses during the end of that year and the following spring amounted to no less than 3,000,000 sheep. In his Report to the 'Journal of the Royal Agricultural Society'[1] Mr. Finlay Dun estimates that the same number of sheep died or were sacrificed from rot during the following year. As this is equivalent to the loss during each year of about one-tenth of the total number of the sheep in the United Kingdom, and represents the loss of six or eight millions sterling[2] per annum, the serious nature of the epidemic will be only too readily seen. Such a loss would be most grievous at any time, but was especially so at a time of bad seasons and wide-spread agricultural depression.

"A portion of the loss falls of course upon the consumer, as is shown by the increase in the price of mutton. Furthermore, the quality of a portion of the supply which comes to the market is necessarily poor.

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[1] See p. 19.

[2] It is very difficult to ascertain the real loss in money, as rotten sheep are frequently sold for food, though at a considerable loss. But in very many instances the animals were sold merely for the price of the skins.

"When the disease had spread so widely and had become so exceedingly destructive, it was doubly necessary that we should bestir ourselves and try all possible preventive means.

"But what were the right measures of prevention? Here, unfortunately, was the great difficulty. Nothing exact had been found out as to the way in which the fluke entered the sheep, and we had to contend against an insidious enemy who was invisible to us, to strike blindly and in the dark.

"In this state of uncertainty it was a matter of national importance that the whole question should be investigated, in order that it might, if possible, be discovered what were the proper preventive measures to be employed. The Council of the Royal Agricultural Society therefore provided the funds needful to procure costly but indispensable apparatus and material. The investigation thus originated began in the summer of 1880, and was brought to a successful close in the autumn of 1882.

"What was really known in 1880 came very briefly to the following. The liver-rot was a parasitic disease due to the presence in the bile-ducts of the livers of the diseased animals of great numbers of liver-flukes. Animals were liable to contract the rot when allowed to graze on low-lying, wet, or ill-drained lands, and especially on ground subject to floods.

"So much was clearly proved. In addition, it was believed by men of science, from what was known of the animals most nearly related to the liver-fluke, that there were larval forms inhabiting some snail or slug, and that the larvæ were subsequently taken up by the sheep when grazing. Some had suggested water-snails, others land-snails or slugs, and numerous attempts to solve the question had been made by various eminent zoologists; but all had proved fruitless, and, notwithstanding its great practical importance, the problem remained unsolved.

"Now, however, the mystery has been cleared up, and I will proceed to explain it in order, step by step, so that I may afterwards show how and where preventive measures are to be applied.

"PART II.—LIFE-HISTORY OF THE LIVER-FLUKE

"Before giving the life-history of the liver-fluke, it will be well for me to explain a wonderful peculiarity in the manner of the multiplication and spread of the animals belonging to the group of Flat worms of which the liver-fluke is a member. The fully grown adults live as parasites in some kind or other of backboned animal, such as a sheep, and there multiply by producing eggs. Each of the eggs give rise to an animal, which is never like its parent, never does become like it, and never lives where its parent lives. It enters some snail or slug, and there grows and multiplies, not in the common way by producing eggs, but by giving rise to germs within itself. Calling the animal which is hatched out of the egg the first generation, these germs will form the second. There may be a third and a fourth, or even more generations in the snails, all these arising in the same way as germs; but at length a form arises which is destined to leave the snail in some way or other to be swallowed by the backboned animal with its food, then grow much in size, become adult, and reproduce itself by eggs.

"The snail or slug which harbours the first, second, and following generations is called the intermediate host, the backboned animal being the ultimate or final host, and there is thus a constant alternation of one generation living its adult life in the backboned animal, and of one or more generations in the snail or slug. This is an example of what naturalists call an *alternation of generations.*

"In the case of the liver-fluke there are at least two generations which live the whole of their adult lives in the particular snail which has now been clearly proved to serve as the intermediate host of the fluke. The third generation arises as a germ in the snail, and whilst still a minute larva passes in the manner explained below into the sheep. That is to say, supposing we start with the fluke as it is found in the sheep, its child does not grow up into an animal like the parent, nor does the grandchild do so. Both child and grandchild look very different from the true liver-fluke, and live in the snail; but the great-grandchild, forming the third generation, does, as a rule, grow up into a true liver-fluke and live in the sheep.

"Wonderful as this may seem to any one who has not studied the marvels of animal life, the fact of alternate generation has been established beyond all doubt, not merely for the liver-fluke, but also for numerous other forms of life, which, however, do not at present concern us.

"**The Eggs of the Liver-Fluke.**—The adult fluke, whilst living in the bile-ducts of the sheep or other rotten animal, produces vast numbers of eggs. The bile-ducts (popularly known as the *pipes*) become large, and their walls thick, owing to the presence of the parasites. The bile contains numbers of eggs too small to be separately recognised by the naked eye, but which are nevertheless present in such quantities that they give it a dark colour. In some of the small ducts where the eggs have not been washed away by the bile, they may be present in such enormous numbers as to form a stiff dark-brown mass, looking like fine wet sand, and completely blocking up the inside of the duct.

"The eggs are very minute indeed, being only $\frac{1}{200}$ of an inch in length; but they may be rendered visible to the naked eye by placing some of the dark-brown contents of the bile-ducts into a glass-vessel with water and shaking it up. On now holding the vessel up to the light, the tiny eggs will be seen as brownish specks suspended in the water. If they are very numerous, they will colour the water a light brown, or may even give it a dark coffee-colour. They are a little heavier than water, so that if the vessel is allowed to stand for an hour or two all the eggs will fall to the bottom, and leave the water colourless.

"The number of eggs produced by each fluke is very large, and its fertility has been underrated. In one case I obtained 7,000,000 eggs from the gall-bladder of a single sheep suffering from the rot, and as the liver contained about 200 flukes, this gives an average of 37,000 eggs to each fluke. And these eggs were found in the gall-bladder alone; the liver must have contained at least as many more, and eggs had been passed copiously by the sheep for many months. The number of eggs produced by a single fluke may be safely estimated at half a million, a number more easily spoken of than realised.

"It is very important that we should know more about the egg, for it forms the starting-point of new generations; but to know more about the egg, it is necessary to see it highly magnified by means of the microscope. Figure 1 shows an egg thus seen. It is an oval body, with a transparent shell, which allows the contents to be distinguished. One end is a little rounder and blunter than the other, and shows a line marking off a rounded portion which forms a lid to the rest of the shell. A little below the lid is a small round mass, which is the present condition of the first

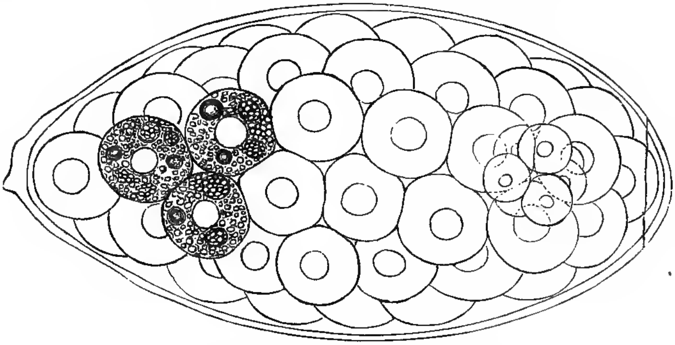

FIG. 1.

Egg of the Liver-fluke examined shortly after it was taken from the liver of a sheep. At the right-hand end of the shell may be seen the line marking off the lid, and a little to the left, the embryo in a very early stage of development. The embryo is surrounded by round masses which serve as food; they are all of them granular, but only three at the left-hand side have been fully drawn. Magnified 680 times. (Original.—A. P. T.)

generation or animal which will ultimately be developed from the egg. The remaining contents of the egg are simply a store of food for the benefit of this animal.

"So long as the egg remains within the body of the sheep no further change takes place.

"Under natural conditions, however, the eggs of the fluke are washed away by the bile into the intestine, and, passing through the intestine uninjured, are at length distributed wherever the droppings of the infected animals fall. If they fall on to wet or marshy ground, or are washed by rain into ditches, ponds, or brooks, further changes occur, and in each egg is formed the first generation or animal, which we may term the *embryo*, so long as it is in the young condition.

"Not only moisture, but also a certain degree of warmth is required for the growth of the embryo within the egg. A temperature of about 74° to 78° Fahr. is the most favourable, and then the embryo is formed in about two or three weeks; with less warmth, progress is slower, and with an average temperature of 60° the growth occupies two or three months. Whilst the temperature is very much below this, as in winter time, the egg does not change at all. It will be seen, therefore, that the embryo will not hatch out in the winter time, and that eggs which fall into suitable places at this season will only be hatched out as the warm weather comes on at the end of spring or beginning of summer.

"But all eggs do not hatch out in the same time; a certain number are hatched out on every successive day for some weeks or even months, and at the end of this time some of the eggs may remain in the same condition as when just taken from the liver. No explanation can be found in the eggs themselves of the very variable time required for the growth of the embryo, but the fact is of much practical importance, for *eggs scattered over any damp ground may render it dangerous for a long period.*

"Figure 2 shows a fluke-egg at the time when the embryo is fully formed within the shell, and is ready to hatch out. The embryo lies curved on itself at one side of the egg, and on the other side are the remains of the food with which it was originally provided. The head-end of the embryo is directed towards the end of the egg which has the lid; and between the embryo and the lid is a cushion, or pad, of stiff jelly-like substance. It will be seen that the surface of the body is covered with what look like hairs (still more plainly seen in the free embryo, Fig. 3). They are not really hairs, but can be moved; they are known as cilia, and it is by their means that the embryo swims, for they act as so many paddles in propelling it through the water.

"Let us watch the embryo as it hatches out. It moves within the egg, the movements becoming more marked, until at last, the body being stretched out suddenly to its full length, so much pressure is brought to bear against the lid that it flies open as if moved by a spring. The cushion of jelly-like substance pours out, the embryo thrusts the forepart of its body out of the shell, the cilia (or paddles) begin to move as soon as the water touches them, and the animal, after a short struggle, succeeds in drawing the whole of its body through the narrow opening of the shell, and glides away with ease and rapidity through the water.

"Figure 3 shows the embryo as it appears when swimming freely through the water. This figure is of course very highly magnified; its real size is so minute that it can only just be detected by the naked eye, even under the most favourable circumstances. It has a conical shape—that is to say, it is not unlike a sugar-loaf in form—and it is about $\frac{1}{200}$ of an inch in length. The

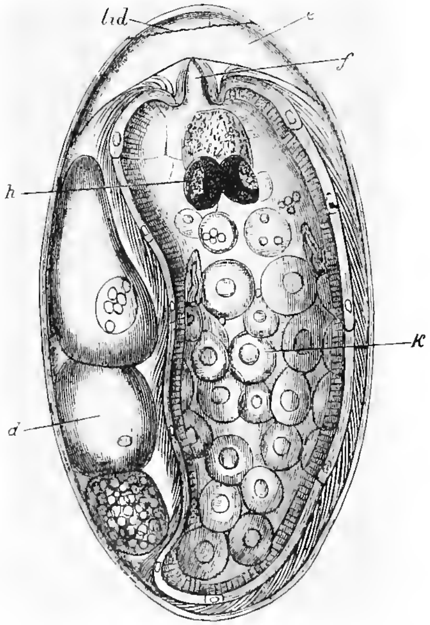

FIG. 2.

Egg of the fluke containing an embryo ready to hatch out: *d*, remains of foods; *e*, a cushion of jelly-like substance; *f*, boring-tool of the embryo; *h*, eye-spots; *k*, germinal cells. Magnified 680 times. (Original. —A. P. T.)

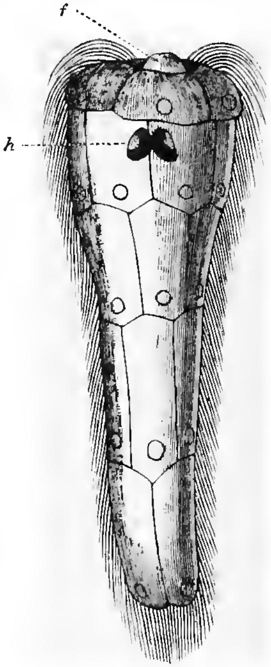

FIG. 3.

An embryo as it appears when swimming in the water; *f*, boring-tool; *h*, eye-spots. Magnified 500 times. (Original. —A. P. T.)

broader end is always directed forwards, and in its centre is a short peg-like projection, which is used as a boring-tool, and can either be drawn in or thrust out. The whole surface of the animal, with the exception of the projection just mentioned, is covered with the long hair-like paddles or cilia by means of which it swims, with the boring-tool drawn in, swiftly and restlessly through the water. It is exceedingly interesting to watch it speeding through the water; it is wonderfully active; sometimes it goes rapidly forwards, revolving upon itself like a top, just twisting a little from side to side, as if searching for something. At other times, by curving its body, it sweeps round in circles, or, curving itself yet more, spins round and round the same spot, without moving from it.

"Towards the front end of the embryo are two black marks (Fig. 3, *h*); they have the shape of two half-moons placed back to back. These are very simple eyes, and though they cannot give the embryo the power of seeing very distinctly, yet they render it very sensitive to light, and are no doubt of very much help to it in searching for its new home.

"When the embryo, in moving through the water, comes in contact with any object, it pauses for a moment, and feels about, as if trying to discover its nature; and if not satisfied, it darts off hastily again. But if the object be the particular kind of water-snail known as *Limnæus truncatulus*, it at once tries to bore into it. This snail is a very common one; but it is so small that it usually escapes notice, and hence it has no common or popular name. More will be said about it further on (p. 181). Under ordinary circumstances, the boring-tool in the head of the embryo (*f*, Fig. 3) is short and blunt, but as soon as the animal begins to bore, it becomes longer and more pointed. The embryo spins round and round on itself, just as the handle of a gimlet is turned, the hair-like paddles working vigorously, and pressing the little embryo against the surface of the snail. The pressure is increased by the body of the embryo being alternately drawn together and then suddenly stretched out. As the boring-tool sinks further into the substance of the snail it becomes longer and longer, until at length it reaches five times its original length (see Fig. 4), and the substance of the snail is forced apart as if by a wedge; and a gap is

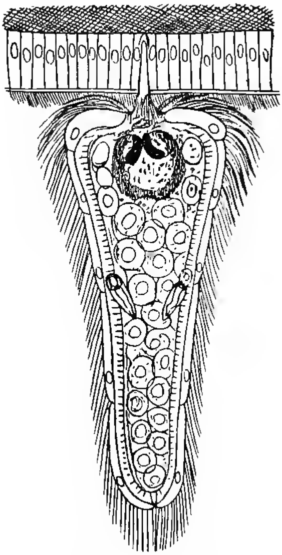

Fig. 4.

Embryo of Liver-fluke boring into a snail. Only a very small part of the snail has been drawn. Magnified 370 times. (Original.—A. P. T.)

thus made through which the embryo squeezes its way into the snail.

"Figure 4 shows the embryo whilst in the act of boring into a snail; only a very small portion of the snail's body has been drawn.

"It may be interesting for me to state briefly how the further development of the embryo within the snail was traced. Very large quantities of eggs were collected from the livers of rotten sheep, and hatched out in water. The embryos were then transferred to vessels of water containing many different kinds of snails, and their behaviour watched. When it was discovered that the embryos bored into the particular kind of snail called *Limnæus truncatulus*, large numbers of this kind were got. Embryos of the liver-fluke were allowed to bore their way into them, and then they were dissected at definite intervals—some three, six, or twelve hours later, others on each successive day, until the whole history was traced. In this way the changes passed through by the animals found in the snail could be followed step by step, and the relation of the different generations proved beyond any possibility of doubt.

"The embryo of the liver-fluke will not bore into all snails alike; the only other kind of snail into which I have found it enter at all is the one called *Limnæus pereger*. But it is only into the very youngest and smallest snails of this kind that the embryo will force its way, and even these do not afford a suitable place for its further growth, for every embryo that succeeds in entering perishes at an early stage.

"The embryo seems to know by instinct the right kind of snail. Thus I have placed large numbers of freshly hatched embryos in a small vessel of water containing *Limnæus truncatulus* and several other kinds of fresh-water snails; and on subsequently examining them all, have found the specimens of *Limnæus truncatulus* to contain as many as fifty or more fluke-embryos each, whilst the other kinds of snails were entirely free from them.

"The natural place for the further growth of the embryo is either in or near the lung of the snail. Once safely lodged in the suitable position, the embryo undergoes a great change of form. It is now settling down to a sluggish parasitic life. It no longer needs the paddles to propel it through the water, and they are therefore thrown off. It no longer needs eyes to help it to find its way about, for it scarcely stirs in the snail, and so they get indistinct, and may at length be altogether lost. The form of the body is also changed, and, instead of being like a sugar-loaf in shape, it becomes oval.

"Figure 5 shows the animal whilst the change is taking place. Figure 6 shows it as soon as the change is completed. We need a name by which to distinguish this first generation in the snail, and so will call it by its English name *sporocyst*, which simply means a bag of germs. This is literally what it becomes as it grows inside the snail, its host. It lives entirely at the expense of the juices of the snail, and the rapidity of its growth depends upon the warmth of the season. In ordinary July weather it will reach its full length of $\frac{1}{40}$

of an inch by the end of the first fortnight. In colder weather, however, growth is much slower; and in winter time very little progress is made, even in three or four months.

"Figure 8 shows a full-grown sporocyst; it contains about half a dozen germs of different sizes. They are round at first, then they get longer, and finally take the outward shape of a sack. At the lower part of the figure is one which is just ready to hatch out, lying with its head directed downwards. This belongs to the second generation; it will be seen that it is different from the sporocyst, and it is called a *redia* after the celebrated anatomist Redi. As soon as the young redia is ready to leave, it breaks its way through the wall of the parent; the wound formed by its forcing its way through

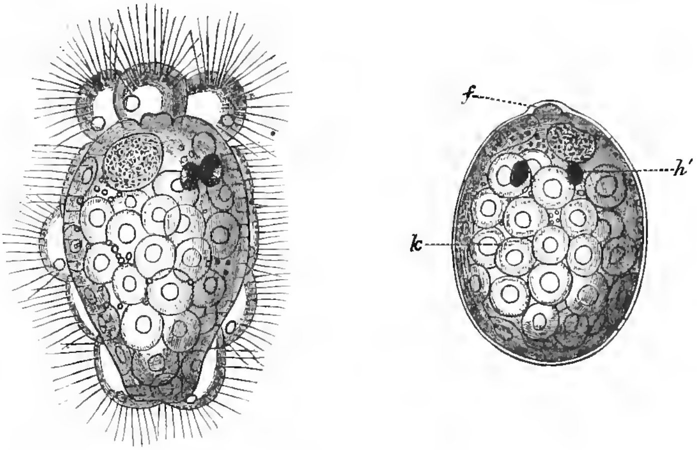

FIG. 5. FIG. 6.

Fig. 5, on the left, shows the change of the embryo into sporocyst just after it has entered the snail. Fig. 6, on the right, shows a young sporocyst produced by the change of the embryo; *f*, boring-tool; *h'*, eye-spots disappearing; *k*, germinal cells. Magnified 500 times. (Original.—A. P. T.)

immediately closes up, and the remaining germs continue to grow. In this way each sporocyst produces about half a score of rediæ. But there is yet another way in which the sporocyst multiplies, namely, by the division of one

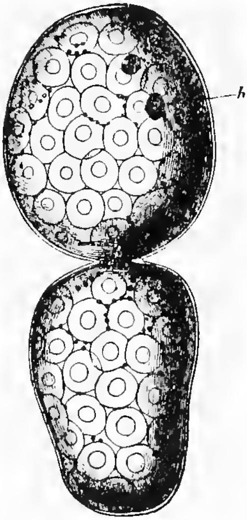

Fig. 7.

A young sporocyst dividing into two: *h′*, eye-spots disappearing. Magnified 500 times. (Original.—A. P. T.)

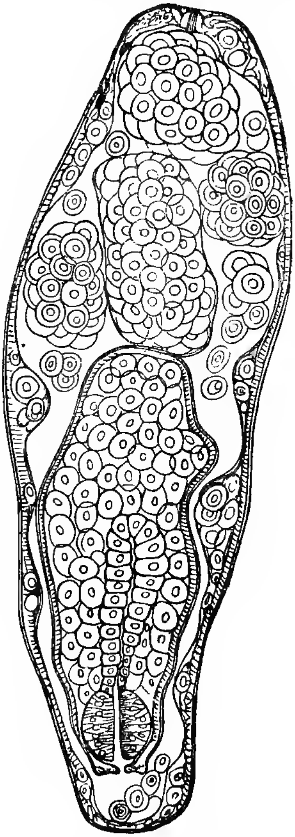

Fig. 8.

A full-grown sporocyst (the first generation) of the Liver-fluke. It contains several germs in different stages of growth. The largest, at the lower end, has assumed the characters of a redia. Magnified 230 times. (Original.—A. P. T.)

sporocyst into two across the middle, as shown in Fig. 7. This is worthy of mention here, as it causes a still greater increase in the number of the parasites within the snail.

" Let us return to the rediæ which compose the second generation. Figs. 9 and 10 (p. 176) show two free rediæ ; the former is nearly half-grown, and the latter is adult. The rediæ are much more active than their parents, and migrate from the lung into the other organs of the snail, and particularly into the liver, upon which they feed. A redia differs from a sporocyst, its parent, in several points. The most important difference is that the former has a mouth and an intestine (Fig. 10, *in'*) shaped like a bottle, whereas the sporocyst has none. Its habits are more active ; towards its hind end are two short projections (Fig. 10, *r*), which serve as legs of a very simple kind, and prevent the animal from slipping backwards as it moves through the body of its host.

" If an infected snail which has a clean and transparent shell be chosen, the rediæ may be watched by the aid of the microscope as they move inside the living snail.

" In forcing their way through the body of the snail the parasites necessarily do a great deal of harm ; so much indeed, that in my experiments in the laboratory I found very few snails live many weeks after infection. In fact, the fluke disease is, in the laboratory at least, more destructive to the snail than it is to the sheep.

" Within the redia are found germs, the third generation, which at first are very like those produced in the

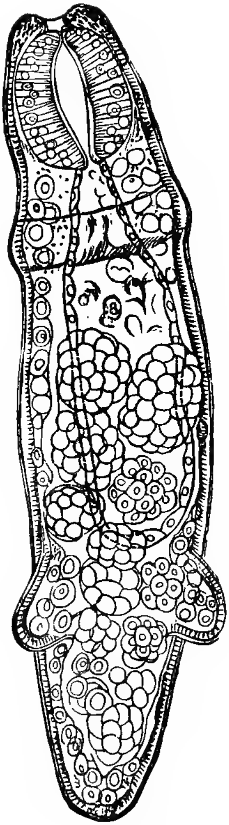

Fig. 9.

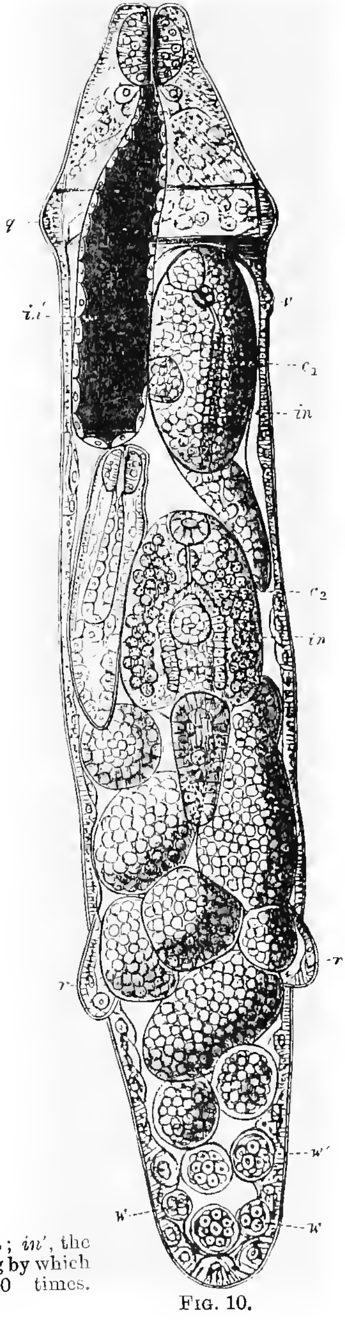

Fig. 10.

Fig. 9.—A young redia (second generation) of the Liver-fluke, with the contents forming into germs of the third generation. Magnified 230 times. (Original.—A. P. T.)

Fig. 10.—A full-grown redia (second generation) of the Liver-fluke. It contains a large number of germs of the third generation. Two of these are so far advanced that they show the characters of the tailed larva or cercaria. It contains also on the left hand a young redia. c_1 and c_2, the two cercariæ; *in*, intestine of cercariæ; *w*, *w'*, germs in a very early stage; *r*, *r*, the processes which serve as feet; *in'*, the intestine of redia; *v*, the birth-opening by which the cercariæ leave. Magnified 120 times. (Original.—A. P. T.)

sporocyst. But later on we see that each germ becomes an animal shaped like a tadpole, with a flat oval body and a long, slender tail. This animal is usually called a *cercaria*, the name simply meaning that the animal has a tail.

"An adult redia, such as is shown in Fig. 10, may grow to the length of one-sixteenth of an inch. It contains about a score of germs in all the different stages of growth; there are usually two or three so far advanced that they have become tadpole-shaped and are ready to come forth. They escape from the parent by a special opening (Fig. 10, *v*), and then crawl or wriggle their way out of the snail.

"Now the tadpole-like animals are destined to enter the sheep and there become true liver-flukes, and I shall have to show how they get inside it.

"When the snails infested with the above-described forms of the liver-fluke are kept in an aquarium, the cercariæ or tadpole-shaped larvæ may occasionally be found swimming about in the water in a very lively manner. Fig. 11 shows a free cercaria as it appears when swimming. It has a flat oval body about $\frac{1}{90}$ of an inch in length, with a tail more than twice as long. There are two suckers (y and y_1) corresponding to those of the adult fluke, and at the sides of the body are many granules arranged in rounded masses (cy).

"The free-swimming life of the cercaria never seems to last long, for on coming in contact with the sides of the aquarium or the water-plants contained in it, the little animal soon comes to rest, draws its body up into a round ball and exudes from the whole of its surface a gummy substance containing many granules (see Fig. 12), which are the same as those already described as forming masses at the sides of the body of the free

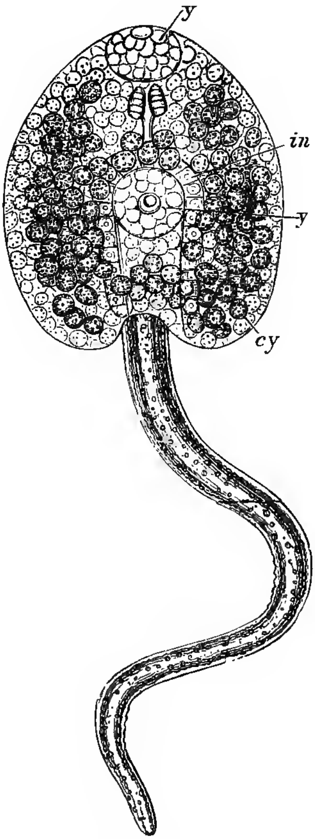

Fig. 11.

A free cercaria (third generation) of the Liver-fluke as it is seen when swimming in the water; y, y_1, the two suckers corresponding to the suckers of the adult fluke; *in*, intestine; *cy*, the rounded masses at the sides of the body which provide the material for the formation of the cyst or envelope. Magnified 160 times. (Original.—A. P. T.)

cercaria. The tail meanwhile is wagged violently, and before long a more vigorous movement throws it off altogether. The gummy substance hardens on exposure, and the body of the cercaria is thus enclosed in an envelope which protects it from injury.

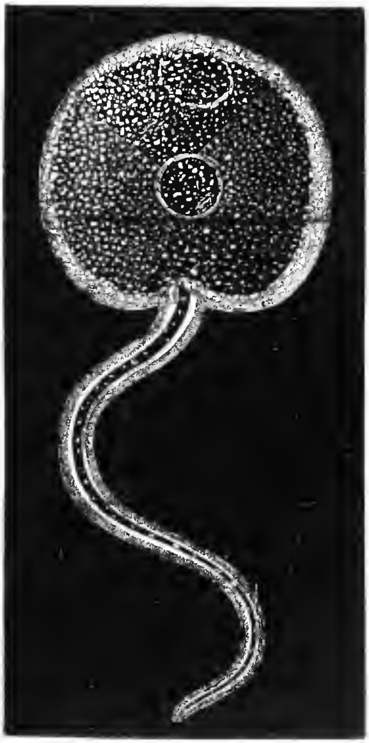

Fig. 12.

A cercaria in the act of forming its cyst or envelope. Magnified 160 times. (Original.—A. P. T.)

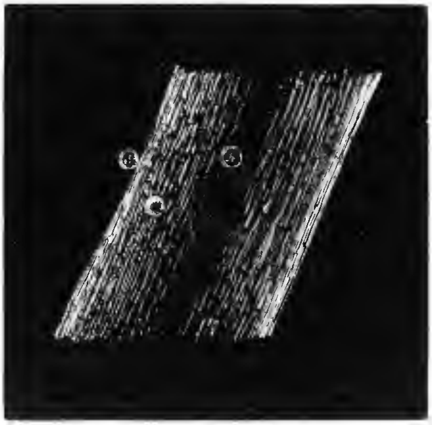

Fig. 13.

Three cysts of the Liver-fluke attached to a portion of grass-stalk. Each cyst contains a young fluke, which remains quiet until the cysts are swallowed with the grass by a sheep when grazing. Magnified 10 times. (Original.—W. H. J.)

"These envelopes are termed cysts (the word cyst meaning a bladder). They are snowy-white, and numbers of them may be found adhering to the walls of the aquarium in which the infected snails are kept, or attached to the dark-green leaves of the water-plants.

"If the snails are crawling on the margin of a ditch or over a damp field, the cercariæ on leaving the snail at once proceed to form their envelopes or cysts at the bottom of the grass, and so attach themselves to the stalks, or leaves, near the roots.

"Fig. 12 shows a cercaria in the act of forming its cyst, and Fig. 13, which is less highly magnified, shows three fully-formed cysts adhering to a portion of a grass-stalk. As even the latter figure is magnified to ten times the actual size of the object, the minute size of the cyst will be easily appreciated. They are really only one-hundredth of an inch across.

"These cysts are the form in which the liver-fluke is swallowed by the sheep, and the animals within them are young flukes. They remain adherent to the grass until the time comes when they are picked up by the sheep feeding on the ground. They may be compared to the pupæ or chrysalides of insects. It must, however, be remembered that whilst the perfect animals emerge from the chrysalides of insects of their own accord as soon as they are ready to do so, and live a free-winged existence, the animals will only come forth from the cysts of the liver-fluke when the grass or plant to which they were attached had been swallowed by some sheep or other suitable animal. If the cysts are not so swallowed within a few weeks, the young flukes which they contain will perish.

"The number of cercariæ descended from a single fluke-egg cannot be less than 200, and is sometimes much larger. For the rediæ forming the second generation, instead of producing cercariæ, may, and perhaps as a rule do, give rise to another generation of daughter-rediæ resembling themselves, and these then produce cercariæ. When this is the case, a single fluke-egg may give rise to more than a thousand cercariæ. It will be seen, therefore, that not only does the race of the liver-fluke multiply and increase abundantly in the sheep by producing myriads of eggs, but that there is a further and great increase of the forms within the snail. If only the greatest degree of ordinary increase were reached, a single fluke might give rise to more than a hundred million descendants in the next generation, of liver-flukes proper, inhabiting the sheep. But, fortunately for farmers, the chances are enormously against any such disastrous increase.

" *The habits of Limnæus truncatulus.*—The habits of the snail *Limnæus truncatulus*, which serves as an intermediate host (see p. 197), are of much importance, for they show how the snail is likely to become infected with the larval forms of the liver-fluke, and also how the cysts are distributed in places where they have a good chance of being picked up by the sheep.

" *Limnæus truncatulus* (Figs. 19, 20, p. 198) is a fresh water snail, with a brown spiral shell; it is very common, and has a very wide distribution over the world. It is very small, its shell never reaching more than half an inch in length, whilst it is usually much smaller, a common variety in England scarcely ever measuring so much as a quarter of an inch. Owing to its small size it often escapes notice, or is taken for the young of some other kind of snail, so that it has no popular name. Two or three of the kinds of snails most closely allied to *L. truncatulus* (for instance, *Limnæus pereger*) may occasionally crawl out of the water for short distances; but in *Limnæus truncatulus* itself, the habit is so much more strongly developed, that the snail should be termed amphibious. Indeed it is oftener found out of the water than in it. When kept in an aquarium it quits the water, and as often as it is put back, insists on crawling out again, so long as the necessary strength remains. It is said to breed upon the mud on the banks of ditches. Although so common, it is often very difficult to find, no doubt owing to its minute size and its habit of wandering from the water.

"As showing how much this snail lives out of the water, it may be interesting to give my own observations. I have related in a former paper that I was quite unable in 1881 to get *Limnæus truncatulus* for my experiments, nor did I succeed in doing so until July of the following year, when there were floods on the river Isis near Oxford. The waters brought this snail down in vast multitudes, probably from its breeding haunts in marshy places up the river. It was extremely abundant, so numerous indeed, that at a single sweep of a small hand-net repeatedly gave me more than 500 examples, and this was in a ditch where the year before I could not obtain a single *L. truncatulus*. All along the margins of the ditches the ground was covered by them, and they were found abundantly on the flooded ground.

"On returning three weeks later to the same ditch I was unable to find a single example alive in the water. As I had not sufficient leisure on this visit to examine the ground near the ditch, I returned for the purpose of doing so eight days later. There had been dry weather since the flood, but early that morning heavy rain had fallen, and I found numbers of specimens of *L. truncatulus* on the gravel of a path near the ditch, and these seemed to have crawled out of the grass when revived by the rain. At the roots of the grass, all along the margin of the ditch, others were found in abundance. Some few shells were quite empty, but the majority contained the dried remains of the snail, which had shrunk far back into the spire of the shell. Most of these appeared to be quite dead, but were, however, merely dormant, for on placing them in water the tissues imbibed moisture and assumed their natural bulk; and after a few hours the snails had regained their full activity, and were seemingly none the worse for their prolonged drying up.

"To test the power of resisting drought possessed by the snail, I collected a number of specimens, and placed them in an open vessel on a shelf in a dry laboratory in a position where the sun fell upon them for an hour or so daily. I found that rather more than half of them withstood twenty-six days of this treatment, and some few revived after more than six weeks. That the snails can live on moist ground, quite away from any quantity of water, for considerable periods, is sufficiently proved by the fact that I have kept them alive for eleven weeks on moist grass and moss, even when infested with the larval forms of the liver-fluke.

"It is clear, therefore, that the kind of snail under consideration may be brought in great quantities by floods, and may be left on the fields when the waters pass away. The snails thus left continue to wander and feed, so long as the bottom of the grass remains moist. Their numbers are recruited from surrounding ditches and streams. Even on land *which is not liable to floods this snail may exist in large quantities,* having crawled from the ditches, ponds, streams, and marshy spots, through the moist grass. A drought may render the snail dormant, but, unless continued too long, it revives at the first shower of rain.

"If there are fluke-eggs on the ground, the embryos hatched out of these will gain entrance to the *Limnæus truncatulus* living in wet places. Owing to the habit which this particular snail has of living so much out of the water, either on the banks of ditches, or further away towards the centre of the fields if they are damp enough, the cercariæ (the larval forms destined to enter the sheep) will, on leaving their host, form their cysts on the grass in the places where they will have the best chance of being transferred to the sheep grazing on the ground.

"Man himself sometimes serves as host to the liver-fluke, and in this case the cysts containing the young flukes are probably eaten with watercress.

"*Growth and Duration of Life of the Fluke in the Sheep.*—From observations which I need not describe here, as they have been given in a former Report,[1] it appears probable that at least six weeks elapse from the time the fluke is swallowed by the sheep before the parasite becomes adult and begins to produce eggs. A very great increase in bulk occurs, for when the young fluke is introduced it is perhaps only $\frac{1}{80}$ of an inch in length, whereas the adult fluke reaches an inch or an inch and a third. A change occurs also in the form of the body, as will be seen from Figs. 14, 15, 16, and 17; it is due to the more rapid growth of the hind part of the body, which contains the reproductive organs (Fig. 18).

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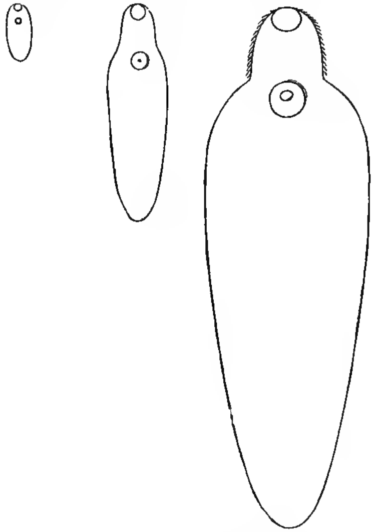
[1] "Journal of the Royal Agricultural Society," 1881, p. 25.



Figs. 14, 15, 16.

Three young flukes from the liver of a sheep to show the change in form during growth. All are magnified $7\frac{1}{2}$ times. Fig. 14 (on the left) represents the smallest fluke I have ever found in a sheep; it was only $\frac{1}{24}$ of an inch in length. Fig. 15 (in the centre) shows the shape of a fluke $\frac{1}{8}$ of an inch long, and Fig. 16 (on the right) shows a fluke which has reached $\frac{1}{3}$ of the full length of the adult animal. (Original.—A. P. T.)

"Of great practical importance is the question how long the fluke remains alive within the sheep. For it will depend upon the length of this period whether or not it is worth while trying to keep the infected animals alive until the life of the fluke has reached its natural limit.

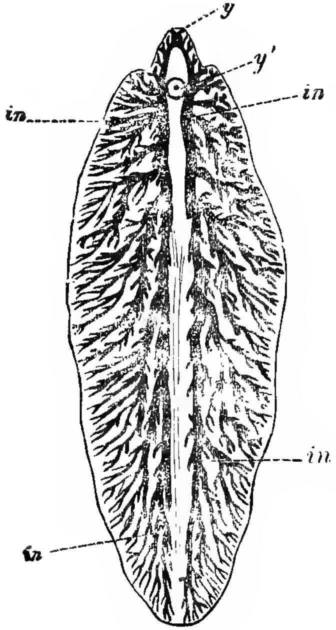


Fig. 17.

An adult fluke showing the branched digestive tract: *y*, the oral; *y'*, the ventral sucker; *in*, the branched intestine. In the centre, between the two main branches of the intestine, lies the chief trunk of the water-vessel. Twice the natural size. (Original.—W. H. J.)

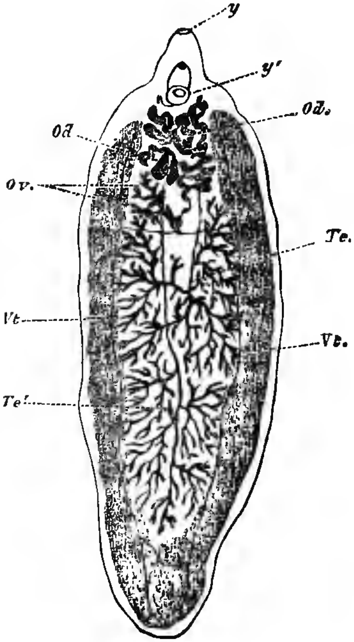


Fig. 18.

Another view of an adult fluke, showing the reproductive organs: *y*, the oral; *y'*, the ventral sucker; *Od*, the oviduct; *Ov*, the ovary; *Vt*, the vitellarium or gland that forms the granular yolk-cells surrounding the embryo in the egg; *Te*, the anterior; *Te'*, the posterior testis; their ducts run forwards. The generative opening is in front of the ventral sucker. Twice the natural size. (Original.—W. H. J.)

"The liver-fluke is supposed by some to pass out of the sheep at the beginning of summer. If this were the case, its life would not last more than three-quarters of a year. Gerlach states that the fluke always passes out in the months of June and July, but Pech[1] says that he has seen flukes pass out from rotten sheep in autumn and winter, and suggests that they may have lived in the sheep more than a year. I have examined the droppings of sheep in June, sent by the kindness of a veterinary surgeon, which were asserted to contain dead flukes, but the so-called flukes proved on microscopic examination to be masses of discoloured mucus. From my own observations I am able to say that the flukes do *not* always pass out from the sheep in the summer time. There is no time of the year when sheep-livers, containing flukes which are clearly several months old, cannot be obtained. In a former report a case was described in which the flukes within a sheep were proved to have lived for a longer period than one year. The animal took the rot in the autumn of 1879, and when it was killed on the 18th of December, 1880, its liver was found to be still full of flukes.

"**Summary of the Life-History.**—The adult fluke in the liver of the sheep produces enormous numbers of eggs, which are distributed with the droppings of the sheep. If these eggs have moisture and a suitable degree of warmth, they continue to live, and in each is formed an *embryo*. The embryo leaves the egg and swims in search of the particular snail, *Limnæus truncatulus*, within which its future life and growth takes place. The embryo bores into the snail, and then grows into the form which is called a *sporocyst*. The sporocyst gives rise to the second generation. This generation is known as *rediæ.* The rediæ in turn produce the third generation, which has the form of a tadpole, and is called *cercaria.* The cercariæ quit the snail, and enclose themselves in envelopes or cysts, which are attached to the grass. When the grass to which the cysts adhere is eaten by the sheep, or other suitable host, the young liver-fluke comes out of the cyst and takes up its abode in the liver of its host, and the fatal circle is thus completed.

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[1] "Der Thier-arzt," 1873, p. 87.

"It will be seen, therefore, that the fluke-disease is a disease which alternates between a particular snail and the sheep. A sheep cannot take the infection *directly* from another sheep, nor can one snail take it *directly* from another snail. The sheep, by spreading the eggs of the fluke, gives the infection to the snail, and the snail in turn, by harbouring and distributing the cercariæ, conveys the infection to the sheep.

"PART III.—THE PREVENTION OF ROT

"Now that we have followed the whole of the life-history of the parasite, and know where it is to be found and to be fought, at all the stages of its varied existence, we are in a position to discuss the important practical bearings of the question. We may therefore proceed with the consideration of the preventive measures, which, if carefully carried out, will, it is believed, enable us to reduce the losses to a comparatively insignificant amount; and eventually, if all farmers will combine their efforts, totally stamp out the disease, so that it may become altogether a thing of the past.

"Let me first state the conditions necessary for the existence of liver-rot, as proved by the foregoing research, and discuss the measures which will prevent the conditions being satisfied, and therefore prevent the disease itself; and lastly give a summary of the preventive measures.

"The conditions necessary for the existence of liver-rot in any given locality are as follows:—

"1. There must be fluke-eggs on the ground.

"2. There must be wet ground or water during the warmer weather for the eggs to hatch in.

"3. A particular snail called *Limnæus truncatulus* must be present.

"4. Sheep or other animals must be allowed to feed on the same ground, without proper precautions being taken.

"If any one of these conditions remains unsatisfied there can be no fluke-disease or liver-rot in the locality. Let us consider these conditions in detail.

"1*st Condition. There must be fluke-eggs on the ground.*—We have already seen that the fluke whilst in the liver of the sheep, rabbit, or other animal, produces vast quantities of minute eggs, and that these pass into the intestines and are distributed in myriads wherever the droppings fall. So that wherever fluked sheep are kept, there we shall have fluke-eggs.

"In some districts the fluke is always to be found, though in dry seasons it may become scarce. Still a few exist, and these are quite sufficient to keep up the breed until a wet season occurs, when, under the favourable influence of moisture, they increase so rapidly as to produce a devastating outbreak.

" But the fluke disease may appear in quarters where it was previously unknown, and surprise is frequently expressed at the way in which it suddenly breaks out in isolated flocks. The infection, however, may be introduced in many ways. Eggs may be brought in manure; or adhering to the feet of men, horses, or dogs; or they may be conveyed by running water, and especially by floods. Rabbits and hares, too, have much to answer for in distributing the parasite. The same account is given everywhere of the way in which rabbits suffer from rot, and in some neighbourhoods about Oxford they were almost exterminated by it in 1879–80. I have received on several occasions fluked rabbits, and have known them to contain each as many as forty or fifty flukes. Wherever they go, and they often wander far from home, the eggs of the fluke are distributed in their droppings. In a case where infection had suddenly broken out in an isolated flock of sheep at Wytham, near Oxford, I was able to show that the rabbits from the neighbouring woods had introduced the disease.

" So wonderfully fertile is the liver-fluke that, if every egg were safely hatched out and the full average multiplication in the snail were attained, a single rotten sheep might pass enough eggs to eventually give the rot badly to all the sheep in England, some thirty millions in number. Fortunately the chances are very greatly against any flukes being reared from any particular egg. Still we must do all we can to increase these adverse chances, and must begin the prevention of rot by waging a war of extermination against the eggs. If we can destroy or, better still, render impossible the production of nine out of every ten fluke-eggs which are annually scattered in England, we shall so mitigate the rot that, instead of a sheep being infested with two or three hundred flukes, it will on the average contain only twenty or thirty. Now, whilst two or three hundred flukes would destroy a sheep, twenty or thirty will do comparatively little harm.

"The production of fluke-eggs may of course be prevented by killing the sheep as soon as it is known that it is suffering from the rot. Extreme as this measure may seem to some, if the sheep are at all badly rotted it will prove the most economical in the end, especially if the disease is discovered at an early stage. It is better to lose a little at the outset than to run the risk of having finally to sell the sheep for little more than the price of the skin. The quality of the meat will be only slightly deteriorated at first, and there will then be no objection to its use for food. But as the disease advances, the meat will become less and less wholesome, and at last become totally unfit for human consumption.

"There is no cure known for the rot, for the fluke inhabits the liver, an organ which can only be reached through the blood, and it is impossible to prescribe any drug which will harm the fluke without harming the sheep at the same time. It is quite true that if the sheep does not contain too many flukes, it may recover when the natural life of the fluke comes to an end, provided its strength is kept up by a liberal diet. But the life of the fluke may last so long (see pp. 184–7) that even if this method prove successful, it will be very costly, and it is scarcely worth while making the attempt, unless the sheep be of a specially valuable breed, or unless there is reason to believe that it contains only a small number of flukes. If the owner decides to try to keep the infected flocks, they should not be allowed to remain on wet ground, for then the fluke-eggs would have a favourable place for hatching, and the result might be a harvest of death reaped in the following season.

"If rotten sheep are kept at all, let them be placed on dry ground, where the eggs cannot meet with the moisture necessary for their development, and where there is no chance of their being washed into ditches, ponds, or streams. A brook may easily carry the eggs down with its current to land lying at a lower level.

"If there is reason to suspect that a flock of sheep is attacked with liver-rot, either one of the most suspicious-looking should be killed, and its liver examined for flukes ; or, if a microscope is available, the point will be more readily decided by taking a very small quantity of the droppings of the sheep on the point of a penknife, mixing it with a little water on a glass-slide, and examining for fluke-eggs. If the animal contains many flukes, even so small a quantity of the droppings will show several eggs, easily recognised as eggs on account of their perfectly definite shape and yellowish-brown colour. This method of course will only serve to prove the presence of the flukes when the disease has been taken for some time, for the fluke does not begin to produce eggs until it has been in the sheep some six weeks.

"The manure of fluked animals must never be placed on wet ground. If the sheep are kept in a yard, the manure should be collected, and a little coal-tar oil may be added to prevent the development of the eggs; or it should be kept for a considerable time before it is spread on the fields. The livers of rotten sheep should be destroyed, for they contain enormous numbers of eggs; perhaps the simplest way of getting rid of them will be to bury them deep. When livers are not very much injured by the fluke, they are often given to dogs, and there is no great objection to this, *provided they be well cooked first.* Otherwise, if they are given in a raw state the contained eggs will pass uninjured through the dog, and be distributed by it.

"*2nd Condition. There must be wet ground or water during the warmer weather for the eggs to hatch in.*—If the eggs of the liver-fluke are to be hatched, they must be in water, or at least be kept moist, during some weeks of warm weather, or even for some months if the temperature be lower. If the eggs are once thoroughly dried, their vitality is destroyed, the side of the shell being usually crushed in.

"Ground is often, with reference to the rot, spoken of as "sound," or, on the contrary, as "rotting." When the droppings containing fluke-eggs fall on to a field, the rain will distribute the eggs over the surface, washing them down to the roots of the grass. If the soil is light and sandy or porous, the ground will be "sound," for the water will filter into the earth, leaving the eggs on the surface where they will get dried, and so be destroyed. If, on the other hand, the soil is heavy and clayey, so that the rain-water does not sink into the earth, but flows along the surface, the ground is "rotting." For, as the water flows over the surface, it carries the fluke-eggs along with it, and deposits them in ditches, holes, marshy places, furrows where the water stands, all of them places where the eggs will hatch.

"The obvious remedy for this evil is to drain the land thoroughly and efficiently, and this will not only do much to prevent the rot, but will have the further advantage of greatly improving the herbage.

"Where it is not practicable to drain the land at once, either salt or lime may be scattered over the surface. Both these substances will destroy the embryos of the fluke, and at a later period the cysts when attached to the grass. And, still further, they will destroy the snails which serve as hosts to the intermediate forms of the live-fluke. The freedom from rot of sheep feeding on salt-marshes is well-known, and is now shown to be due to the poisonous action of the salt on the embryos, sporocyst, redia, cercaria, and cyst, and to its similar action on *Limnæus truncatulus* itself.[1]

"Even a weak solution of salt in water (containing only ¾ per cent. of salt) proves fatal to this snail. Dressings of salt have the advantage over lime in not spoiling the grass for immediate use, whereas lime will do so. It may, however, at times be better for the land itself that lime should be applied. It will be for the farmer to decide which dressing should be used.

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[1] It may be worth noting that watercress should be steeped in salt and water before it is eaten, so as to guard against any possible infection from adhering cysts of the liver-fluke.

" It is naturally of much importance that the salt, or lime, should be distributed at the right time of the year, when fluke-germs and snails are present in the greatest numbers. The snail buries itself in mud, or soil, in the winter-time, and owing to the cold no embryos are hatched out at that time. If the weather be warm in April, it is possible that a few may be hatched out towards the end of the month, but they will not be numerous. In May, however, greater numbers will be hatched, and still more in June and July. These two months are the time of the year when the snails are most liable to be infected. As more eggs are distributed through the whole of the summer by fluked animals, it is clear, of course, that the production of embryos, though in less numbers, will continue from August until the time when the development is checked by autumnal cold.

" Even under the most favourable circumstances it will be seven weeks before the cercariæ are formed within the snail so as to be ready for transference to the sheep. Animals may take the rot as early as June, but this is not of frequent occurrence. In July, however, the germs or cysts on the grass become more numerous, though still comparatively scarce. In August more will be found, but it is in the months of September and October that they are most numerous. These are the most dangerous months. The Northumberland farmers hold that the end of October is the most fatal time for their district. In November the germs are less numerous, and rot is less frequently taken, though there are one or two instances in which the disease has been clearly proved to have been taken as late as the beginning of December.

"Some farmers are inclined to place the dangerous period earlier in the year, dating from the time of a flood in June or July. It may be quite correct to attribute the outbreak to the flood, but the date of the flood may simply be the time when the snails are infected, and not when the sheep take the rot. The cercariæ would probably be matured some two months later, so that the true date of the infection of the sheep would be August or September.

"In the case of snails which become infected late in the year, the different generations will not have time to grow, multiply, and become mature before the cold of the closing year drives the snail into its winter quarters, and suspends for the time the life of the parasites. It is a question of some interest whether the snail and its included parasites can together survive the winter and complete their growth in the following spring. If the parasites are numerous or are far advanced, the snail is so much weakened that, fortunately for us, it will probably succumb to the rigours of the winter. But there can be little doubt that some few will retain their vitality throughout the winter, and with the return of milder weather a fresh start will be made, and that at length the forms destined to be transferred to the sheep will be matured. Some of the cases of early infection in

June are probably due to parasites which have survived the winter in the snail.

"June and July are then the principal but not the only months in which we are to wage war against the embryos; the latter part of August, September, and October, are the months in which especially to destroy the germs on the grass ready for transference to the sheep.

"*3rd Condition. A particular snail called Limnæus truncatulus must be present.*—There seems to be only one snail in England[1] which can serve as host to the intermediate forms of the liver-fluke. Consequently, wherever this snail is absent there can be no liver-rot, and if we could succeed in exterminating it, we should render it impossible for the disease to exist in England.

"The snail, however, is small, and hence difficult of detection, so that all we can hope to do is to limit its numbers in any given locality. There are several ways in which this may be done. First of all, the land should be well drained. I have known an instance in which *Limnæus truncatulus* was found in a small boggy place towards the middle of a field, and was there the means of propagating the fluke. When, however, the marshy place was drained, the snail disappeared from the ground, and with it the fluke-disease. A dressing of lime or salt will, as already mentioned, destroy the snails, and if applied to the ground for this purpose, it should be scattered especially on or near any marshy places, or along the margins of ditches, ponds, or streams, out of which the snail will naturally crawl.

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[1] The snail *L. truncatulus* has a very wide distribution, being found, according to Dr. Gwyn-Jeffreys, throughout Europe, in North Asia, Morocco, Algeria, Madeira, and (doubtfully) Guatemala. The liver-fluke, however, has a much wider distribution, and it follows that there must be in certain countries, supposing L. *truncatulus* to be *really* absent, another snail which can replace it as host. Thus the fluke is found in the United States, where *L. truncatulus* is said not to occur, though several other kinds of snails belonging to the genus *Limnæus* are found. In Australia the fluke occurs both in sheep and in human beings. *L. truncatulus* is stated not to exist there, but eleven kinds of *Limnæi* are recorded. It is probable that in both these countries some other species of *Limnæus* serves as host.

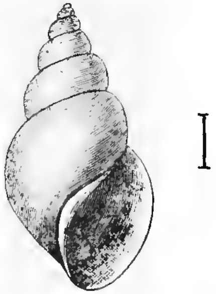

Fig. 19.

The snail, *Limnæus truncatulus*, which serves as host to the sporocyst, redia, and growing cercaria of the Liver-fluke. The drawing is magnified, and the true length is shown by the line at its side. (Original—A. P. T.)

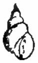

FIG. 20.

Limnæus truncatulus, of natural size. (A. P. T.)

"A flood may bring the snail down in quantities, and scatter it broadcast over fields which were previously free from it (see p. 182). The snails may be infected before they are brought down by the flood, and infection be thus introduced into new areas; or they may become infected subsequently, if there are eggs on the ground. They are drifted everywhere. Flooded land should therefore have the salt or lime scattered over the whole of its surface when the waters have gone down.

"4*th Condition. Sheep or other animals must be* *allowed to feed on the same ground, without proper precautions being taken.*—If any ground is likely to give the rot to sheep, the simplest plan would, of course, be not to allow them to graze upon it, but to keep them on drier and safer land. But such advice would seem a mockery in certain districts, where all the land is more or less unsound. A great deal of such ground would probably be found to be heavy, and in urgent need of drainage. But it must always be remembered that even a sound porous soil may become dangerous in a season of excessive wet, if it lies so low that it becomes clogged with water which cannot be carried off fast enough by the rivers, or if it is flooded.

"If it is necessary to send sheep on to dangerous ground, great care should be exercised in observing the following precautions:—

"Salt or lime may be scattered on the surface at the proper season, to destroy the germs, as already explained.

"Salt should also be used in another way. It has long been known that salt is a preventive when given to the sheep with their food, but many farmers have been slow to use it. There are two reasons for its action. First, it acts injuriously upon the germs of the liver-fluke which may be swallowed; and, secondly, it improves the general health of the sheep, enabling them to digest the germs better. In addition to the salt, dry food should be given, as this will, by keeping them in good health, greatly improve their chance of digesting the young flukes. If the salt be mixed with the dry food, each sheep is more likely to secure its proper proportion, and no more, than if lumps of rock-salt are simply put down for the sheep to lick when they please. Care must, however, be taken that breeding-ewes do not get too much.

"It will scarcely be necessary to give salt to them after November, so far as this particular purpose is concerned, for there will then be very few of the germs or cysts about on the grass.

"In this connection may be mentioned an experiment recently tried by Mr. T. P. Heath, veterinary officer for Exeter and Devon, and published in the *Western Morning News* for October 14th, 1882. It is especially valuable on account of its definite and exact nature. No sheep had been kept in safety on or near Mr. Heath's farm within living memory. A number of unaffected sheep were selected, and divided into two flocks. One flock was kept as all other farmers' sheep are kept; to each sheep of the other flock was given a quarter of an ounce of common salt, well mixed with half a pint of oats every day that they fed on the *permanent pastures.* Whilst they were feeding on turnips, vetches, etc., this corn and salt allowance was entirely dispensed with. All the sheep were killed in summer. The half fed with corn and salt were quite sound; the other half had flukes in their livers, so that they could not have been kept through another winter. Mr. Heath had no cause of complaint with his speculation, as the subject of his experiment realised a profit of about 50*s.* per head, and the cost of corn and salt did not exceed 3*s.* each.

"Sheep must not be allowed to graze too closely, for they are then specially liable to take the rot. Not only does close grazing imply that food is scanty, and that the health, and therefore the digestive power, of the sheep is likely to suffer in consequence, but the sheep will pick up more fluke-germs. The snail, in crawling about in the grass, keeps, as a rule, at the bottom, close to the roots; the cercariæ accordingly, on leaving the snail and proceeding to form their cysts or envelopes, will attach themselves to the stalks of grass or other plants close to the ground. Hence the closer the sheep grazes the more of these cysts it is likely to pick up. There are many instances on record, and I have myself met with others, in which "hog-jawed" sheep, which are unable to graze closely, have escaped infection when all the rest of the flock have been rotted. The special liability of sheep to the fluke seems in some measure to be due to the fact that it can graze more closely than any other domestic animal.

"**Summary of Preventive Measures.**—I may now give a summary of the preventive measures which have been suggested above.

"1. All eggs of the liver-fluke must be rigorously destroyed; manure of rotten sheep, or other rotten animal, must not be put on wet ground.

"2. If sheep are rotten, let them be sent to the butcher at once, unless they are specially valuable and are not badly fluked. If kept, they must not be put on to wet ground.

"3. Care must be taken to avoid introducing eggs of the fluke, either with manure, or with fluked sheep, or in any other way. Rabbits and hares must not be allowed to introduce the eggs.

"4. All heavy or wet ground must be thoroughly drained.

"5. Dressings of lime or salt should be spread over the ground at the proper seasons to destroy the embryos, the cysts of the fluke, and also the snail which acts as host.

"6. Sheep must not be allowed to graze closely, for the more closely they graze, the more fluke-germs will they pick up.

"7. When sheep are allowed to graze on dangerous ground, they should have a daily allowance of salt, and a little dry food.

"If all farmers will unite in carrying out the above preventive measures, suggested by the knowledge of the life-history of the parasite, there is no reason why the fatal ravages of the destructive fluke should not be so restricted that the losses would at once be reduced to a comparatively trifling amount. There is at present one obstacle in the way of the total extermination of the fluke. So long as rabbits and hares have free liberty to convey the infection from one district to another there will always be a danger of a fresh outbreak in places where the fluke had for the time being been driven out. And for rabbits in a state of nature we cannot adopt preventive measures in the same way that we can for domesticated animals, so that on wet waste lands the breed of flukes may be constantly kept up. Very much, however, may be effected by united action; and if the preventive measures which are now suggested are strictly carried out by all, we shall hear no more of the disastrous outbreaks of the sheep-rot, and something at least will have been effected towards raising the fortunes of British agriculture.

"In conclusion, I desire once more to express my thanks to all the gentlemen who have so readily and courteously assisted my investigations upon their fields. It gives me much pleasure to take this opportunity of thanking Dr. Acland for kindly permitting me to use the Sanitary Laboratory of the Oxford Museum for my experiments, and Professor Moseley for kindly placing all apparatus in the Anatomical Department at my disposal.

"To my friend Mr. W. Hatchett-Jackson, Natural Science Lecturer of St. John's College, Oxford, I am especially indebted, for he has most kindly come to my aid when prevented by my departure for New Zealand from revising the present paper, and has, by undertaking the revision of the proofs of both figures and text, and by making for me some additional drawings, rendered its earlier publication possible."

CHAPTER VII

"COCKLE" IN SHEEPSKINS

COCKLE cannot be classed as a disease.[1] Pain, inconvenience, and suffering are the characteristics of disease, but during a lifetime the most careful observation has not resulted in showing me that sheep suffer any serious inconvenience therefrom. It is a natural consequence which ensues and follows certain changes in the life cycle of the sheep; nevertheless, as a certain amount of inflammation is produced, it may be referred to as a disease in a limited sense.

The pathology of cockle has puzzled the minds of sheepskin manufacturers from time immemorial. Very early in my association with the industry, cockle attracted my notice and curiosity, and inquiries from old and experienced men afforded me no satisfactory answer as to its causes, etc. I felt that if the etiology of cockle had to be studied, it could only be done by long and systematic observation, experiment, and the keeping of close records of results. The conclusions arrived at in this chapter are the results of those observations, experiments, and records, extending over a period of some thirty-five years, and, while they do not pretend to solve the problem completely, it is hoped some light will have been thrown on the pathological aspect of cockle.

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[1] The original article appeared in the *Collegium,* 1908.

Every one who has handled sheep and lamb pelts is familiar with the curious eruption which appears upon certain classes of pelts, particularly during the early or spring months of each year, and known to the Anglo-Saxons under the mysterious title of "Cockle." How such a name came to be applied is almost as obscure as the disease.

The word "cockle" is one in common use for describing a peculiar uneven condition of given substances or the appearance of surfaces, and originally was undoubtedly taken from the crinkled shell of the common shellfish, the Cockle (*Cardium edule*).

The *Century Dictionary* gives the following examples:—

"The sorting together of wools of several natures causeth cloth to cockle and lie uneven." (*Hakluyt's Voyages, II. p.* 162.)

"Parchment does not cockle unless wet through." (*Workshop Receipts, 2nd sec., p.* 251.)

"To rise in frequent ridges."

"Short cockling sea which must very soon have bulged the ship." (*Cook's Voyages*, 1. *III*. 7.)

It may therefore be rightly assumed, that the word has been applied to this special complaint from the appearance caused by the curious eruption on the grain side, characteristic of the cockled condition, that is, the crinkling, wrinkling, and puckering of the grain surface.

"Cockle," as all dealers in sheep and lamb pelts know, is a disturbance of the pelt structure, resembling a hard pimple or boil of a marked and well-defined appearance, dark in colour, especially after liming, and turning to a deep brownish black in the tan liquors. The area covered varies in different skins according to given conditions. The markings range in regular waves or ridges from the spine outward, commencing in the region of the neck and shoulder (*i.e.* the heart), and sometimes covering the whole skin, but frequently ceasing with the ribs.

After depilation the cockle assumes a yellow colour, which deepens in tint as the operations succeed each other, and may be easily taken as a species of gristle.

In mild cases, the wet-work treatment will remove the earlier forms, but when the cockle is of long standing, no treatment at present applied will remove them. After tanning they are particularly apparent, being of a red to a deep red-black shade, or brown, according to the tannin employed, the centre being darker than the surrounding portion. After performing the shaving operation they become more prominent, or sink down and appear thinner and harder than the unaffected parts. The appearance of cockle, during what is known in the trade as the "cockle season," causes many manufacturers to shut off supplies until the shearing season opens.

Cockle is confined to the wool-bearing animals, especially those which may be classed among the fatty pelt group, such as the sheep of Europe, Australia, New Zealand, North and South America, among which it is very prevalent; whereas, among Arabian and Indian and similar breeds of sheep, it is practically non-existent. It does not appear to afflict goat skins.

Cockle does not begin to appear until about the month of December, and continues to increase in virulency until the sheep is shorn, when it entirely disappears. It is quite correct to say that no spring passes without cockle appearing in varying degrees of prominence. It is worse in some seasons than in others, and assumes a severe or mild form at different times.

Such were my earliest observations, which led me to investigate the problem on scientific lines. I decided that the subject must be carefully investigated for many years in the following directions.

Why was it that cockle disappeared within a few days of the act of shearing?

This led me to examine the effect of natural moulting or casting the fleece, in cases where shearing had not been performed, with the result, I noted, that as the wool was shed the cockle disappeared. Here nature was performing a function the causes of which were as yet obscure, but which bore a resemblance to the results obtained by shearing.

How far was the variation in virulency of cockle in certain seasons due to the food supply and its character or nature?

This involved keeping close records of the harvests in the various districts and comparing the results, assuming that the harvests were applied to the feeding of the sheep. The results showed a continuous and confirmatory agreement, that, when grass was prolific and long continued into the autumn, the weather open and the root crops generous for winter feed, the cockle was invariably mild, but if the grass season was short and the root crops failed, and artificial feeding had to be resorted to, the cockle was always severe.

While these observations were being carried out, I persuaded a large breeder of prize Shropshire sheep to permit me to carry out certain feeding experiments. These sheep were selected on account of their yielding cockle under normal conditions in abundance.

Fifteen sheep were taken in November 1888, and divided into three lots of five each; each lot was out to grass until clip time, but the extra fattening food was varied as follows:—

Lot 1. Extra feed of oilcake and dry foods.

Lot 2. Extra feed of oilcake but alternated with roots (mangolds).

Lot 3. Extra feed of roots and moist food only.

When the time arrived for shearing, I had only the right half of each sheep shorn of its fleece. Three days later the whole were killed, and the woolskins were subsequently depilated by me in the presence of witnesses, the depilating material being ordinary milk of lime paste. On examining the pelts, all fifteen showed cockle on the left side, which had not been shorn, and in the following order of virulency:—

Lot 1 displayed cockle in its worst form.

Lot 2 showed cockle in a medium degree.

Lot 3, the cockle was in the mildest form, and comparable with any ordinary season of mild cockle.

An examination of the right side or shorn side gave interesting results as follows:—

Lot 1 bore every appearance of having been badly cockled, but this was rapidly disappearing.

Lot 2, the remains of cockle were only slightly apparent.

Lot 3, cockle had entirely disappeared except in one spot, and there it was in so mild a form as to be scarcely detectable.

The results of those tests and the accumulation of evidence over a number of years conclusively prove that the prominence or virulency of cockle in certain seasons is in a large measure due to the conditions of food supply; also that oilcake and such heating foods are conducive to the production of cockle, whereas, in open seasons when the grass is available and root crops prolific, the cockle is diminished, but still present.

In discussing this problem with a large New Zealand stockraiser who has also studied the question, he gave me the interesting information that, when the grass failed in New Zealand, the shepherds turned the sheep on to the rape grass lands, but they had to exercise great caution on account of its over-heating properties, and, unless carefully watched, the sheep became over-heated, and their ears affected in such a curious manner as to make them diseased and eventually drop off. In his experience skins from such sheep were always very badly cockled. This rape grass yields the seed from which the rape oil cake is made for fattening sheep in Great Britain.

The observation has been made that cockle disappears quickly after the fleece has been removed from the sheep. It is well known that shearing is performed during a time when the grass is not very plentiful—it is just beginning to grow again—and that the artificial feeding of sheep proceeds apace after shearing and yet cockle disappears, but during the past three decades cockle has appeared in the early lambs, whereas it was never known to be present previously to that period. This observation has led pelt sorters to maintain that it is hereditary, which is not the case.

In the chapter on digestion, it was pointed out that when a lamb was born the milk drawn from the ewe went into the final stomach, being a prepared food ready for assimilation into the system. Provided a sheep is not artificially fed with oil-cake and the like, no cockle will appear in the lamb, but as artificial feeding is firmly established, the effect of such milk supply from sheep artificially fed is the same on the tender lamb as upon the mother sheep, but as the lamb begins to assimilate grass so the cockle will disappear, except in cases where the shepherd scatters broken pieces of oil-cake over the grass lands to feed the ewes artificially and to enable them to provide a copious supply of milk for the lambs in order to bring the lambs on with greater rapidity. The lambs, while suckling the ewe, also feed off the broken oil-cake, so that cockle will continue in the lambs, but will gradually disappear as the season advances and the other stomachs are brought to exert their peculiar functions.

Cockle disappears after shearing, and does not begin to reappear until about December, and continues with increasing virulence until clip time again comes round.

With the disappearance of cockle the pelts commence to accumulate fat, and with the appearance of cockle the fat begins to disappear from the skins. This phenomenon is coincident with the growth of the wool. During the first few months of the life of a lamb, the carcase grows at a greater rate than the wool; but there arrives a time when the cold weather intervenes and nature demands extra clothing. It is at this time that the greater growth of development of the carcase is arrested and the surplus fat is absorbed by the wool, which rapidly takes the place previously occupied by the growth of the carcase. Although the carcase continues to increase in weight, it does not do so at so great a rate as the increase of weight of wool. This change is coterminous with the appearance of cockle.

Exactly what part the fats play in the production and growth of wool is not yet understood, but it is an interesting observation that the greasier the pelt the more beautiful and soft is the wool, and the more lanoline the wool carries. Wool is only found on sheep which have greasy pelts; the fur and hair-bearing animals possess skins singularly devoid of skin fat as compared with the skin of a sheep. Cockled skins are invariably devoid of free fat, and the increase of cockle is always coincident with the increased growth of wool.

The explanation of the sheep moulting or casting its wool would appear to be one of nature's provisions, caused by the increased internal temperature and the increased external heat of summer, the period of moulting. In his "Variations of Animals and Plants under Domestication," Charles Darwin says, on p. 120, "Great heat, however, seems to act directly on the fleece; several accounts have been published of the change which sheep imported from Europe undergo in the West Indies. Dr. Nicholson, of Antigua, informs me that, after the third generation, the wool disappears from the whole body, except over the loins; and the animal then appears like a goat with a dirty door-mat on its back. A similar change is said to take place on the west coast of Africa."

Darwin goes on to say: "On the other hand, many wool-bearing sheep live on the hot plains of India." Here I am inclined to think he is in error, because, so far as I am aware, the Indian sheep cannot be classed as wool-bearing, but rather of the hair class. I have examined many sheep in all parts of India, and, so far as my observations went, I could not detect a class which I would group among the wool-bearing genus.

When the wool drops off a sheep the undergrowth resembles short shining hair rather than wool, but as the season advances an automatic change supervenes and the hair rapidly assumes the characteristics of wool. This change is not so marked after shearing. Taking the case of the self-shed sheep, the period of shedding is coincident with the disappearance of cockle and the accretion of the denuded fats in the skin, and, when it has assumed normal proportions, the wool begins to grow. Therefore, what bearing has the fat in the skin upon the growth of the wool?

As previously explained, the skin fats accumulate in lobular clusters in the fatty layer containing the wool roots; they are surrounded with areolar tissue, and with countless arterial blood capillaries interlacing the lobular clusters in every conceivable direction, which convey the fatty elements to these storehouses for future consumption. Leading from these clusters of fat are more vessels which gather around the wool roots and the wool follicles, to which they convey the nourishing fats by means of more or less transparent capillaries (as observed by Malphigi in 1661), from the smallest arteries across to the smallest veins, to be returned to the purifying organs. During the cockly season these storehouses of fat are denuded to supply the food for wool production, and a process of filtration goes on at the base of the clusters of wool. It must be remembered that wool does not grow in the same manner as hair, *i.e.* in almost equidistant and individual follicles, but in grouped masses of follicles, with a marked space between each grouping, in which no wool follicle appears.

A section, or sections, of cockle cut very thin, and suitably stained by treatment with osmic acid, discloses in the centre and lying immediately under the grain a black substance (see photo-micrographs), which on analysis has been shown to consist of a material which is not a cholesterol fat, nor yet a tallow fat, but something between the two. It is not so unsaturated as the first and much more so than the other. It is far more difficult to saponify than the skin fat, but more easily than the wool fat. It is only partially saponifiable with alcoholic potash, but completely saponifiable by the enzymes of the pancreatic juice which contain steapsin, which is therefore the active agent in this respect. Cockle fat would therefore appear to be a mixture of glycerides of higher fatty acids (saturated and unsaturated) with possibly higher alcohols (saturated and unsaturated).

It would therefore seem probable that the metabolism of skin fat to the wool fat *viâ* cockle fat proceeds in the following manner: The palmitin, stearin, olein and linolein of the tallow skin fat are transformed to hydroxy acid glycerides of the recinolein character, thus inducing a hydroxyl group, which is further mutated by the rupture and reduction of the carboxyl group to form higher alcohols.

From the observations made it may be reasonably concluded that cockle is the result of a condition set up during that part of the year when the wool grows more rapidly than the flesh, and when nature makes the necessary provision against the increasing inclemency of the winter months. With the decrease in ratio of flesh and increase in the weight of wool, the surplus of fatty substances finds a natural outlet in the demands made by the increased growth of wool. In spite of the increase in artificial and other methods of feeding, and the requisite amount of fat consumed by the sheep to make up for the loss of natural heat, etc., the quantity of fat is not sufficient to more than supply the demands of the body and wool, with the result that a process of outward filtration takes place within the skin, the wool absorbing all the available fat existing under normal and abnormal conditions in the fatty layer of the skin.

This fat enters the wool by means of the capillaries surrounding, and attached to, the wool root or bulb, and possibly also through the sebaceous glands which surround the wool follicle.

From the microscopic sections of cockle, it would not appear that the *semi-cholesterol-tallow fat*, which is the cause of the eruption, plays any part in the sebaceous glands, but in all cases it is seen as a deposit at the base of the wool-bulbs, which in the case of sheep are always grouped in bunches. The eruption is therefore due to the presence of a fat-like material at the base of the follicle-bulbs which has failed to find an outlet, thus producing a strangulation of the follicles and the consequent pimple-like effect.

This wax-like fat is rendered more insoluble by the subsequent process of liming, but is readily removable by means of bates containing the enzymes of the pancreatic juices, trypsin and steapsin, and subsequent working out over the beam during the act of scudding.

Note.—During the shearing operation observant shearers have called my attention to a mass of white scurf-like deposit on the surface of the skin, which is especially heavy in quantity on those sheep which most clearly show the eruption of "cockle" to the shearer. From a large number of sheep, I collected about an egg-cup full of this scurf. The collection was very difficult on account of it adhering to the short wool. The shearers speak of it as grease, and it certainly feels greasy. On non-cockly skins this material is absent; at least, it is not visible to the naked eye. In order to see if this substance had any bearing on the cockle, I sent the entire quantity collected to Professor Procter, who very kindly analysed it for me with the following results:—

"Prof. H. PROCTER, M.Sc.F.I.C.
"Asst. Prof. E. STIASNY, Ph.D.
"Leather Industries Laboratories,
"The University,
"Leeds.

"Dear Sir,

"I beg to inform you that the following are the results of analysis of your sample of fat extracted from wool.

Constants of Cockle Wool Fat.

	Cockle wool fat.	Ordinary wool grease (Lewkowitsch).
Sp. gravity	1·0458	0·9413
Iodine value	57·6	17·1
Acid value	10·2	
Saponification value	53·1	102·4
Unsaponifiable	4·1 %	43·1 %
Suspended in aqueous layer after separation	19·2 %	
Fatty acids	60·4 %	59·8 %
Mean molecular weight acids	514·7	327·5

"Fat totally soluble in alcohol—insoluble portion not dissolved by petrol ethyl ether or acids. Saponification and other values on dry soluble portion only, except specific gravity and refractive index which was on whole fat extracted by petrol ether. The insoluble portion was probably a mechanical or colloid suspension. The extraction of the wool was originally made with petrol ether and yielded 12·1 per cent. of fat, including the portion which afterwards would not redissolve, and which amounted to 2·97 per cent. on the *wool.* The latter, after extraction with petrol ether, yielded 6·14 per cent. to alcohol, which was not further examined.

PLATE 27.

This figure represents two vertical ribbon sections cut right through two cockles for the author with a Cambridge microtome in the year 1888. The two ribbon sections were stained with osmic acid, which has made the *semi-cholesterol fat* appear in the top sections as a black spot or spots, at first beginning faint and less pronounced, but increasing in blackness and sharpness as the upper sections are examined. The lower sections contain no cockle fat, and represent the outer ring of the cockle pimple. The upper surface of each section is the grain.

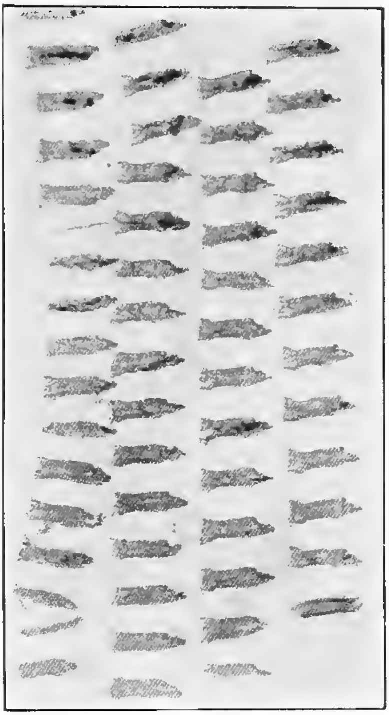
Enlarged about four times from the original slide by the author.

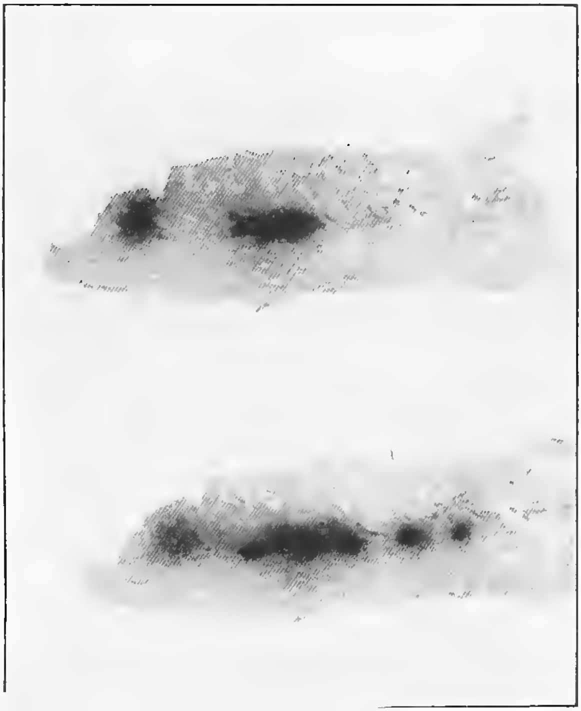
PLATE 28.

The two sections were enlarged direct from two of the upper sections of Plate 27, but from the slide, and are highly magnified.

The cockle is plainly seen as black spots in the fatty layer, and lying below the grain, through which it has not been able to obtain egress.

From a photo-micrograph by the author.




GRAIN.
FATTY LAYER.
LEATHER SKIN OR FLESH.
GRAIN.
FATTY LAYER.
LEATHER SKIN OR FLESH.

"It is obvious from the figures given, that the substance does not bear any close relation to ordinary wool fat, if indeed it is really a fat at all, and it is unfortunate that the total quantity available (about 1 grm. of the extracted substance) was too small for fuller and more accurate investigation. The saponification was not under pressure, but made in the ordinary way with alcoholic potash.

"HENRY R. PROCTER."

It is unfortunate that the quantity was so small; nevertheless, it affords some idea of the character of the surface skin fat off cockle skins. Professor Procter has published a short note in the *Collegium* on this investigation (see *Collegium*, 512, 1912, p. 686).—A. S. J.

CHAPTER VIII

THE PRINCIPLES OF FELLMONGERING AND THE CONSERVATION OF SHEEP PELTS

> "So I set out and rode to Ware, this night, in the way having much discussion with a *fellmonger*, a quaker, who told me what a wicked man he had been all his life-time till within this two years."—PEPYS in his *Diary*.

THE matters referred to in the following pages cover a wide range of relative subjects, each one having a bearing on individual sections or processes, for which no one general and covering term or name is alone applicable; so, for convenience, and so far as it is practicable, the chapter is divided into sections under the headings representing the different processes and in the order in which they occur.

The definition of the word *fellmonger* is to be found in the old Saxon word *fel* or *fell*, meaning a skin:

> "He and alle his kyn at ones
> Ben worthy to brennen, *fel* and bones."
> CHAUCER, *Troilus*, 1, 91.

And the word *monger* is likewise of Saxon origin, meaning one who trades, or deals, or traffics in skins. The compounding of the word *fell* with that of *monger* is obvious and common since remote times:

> "Godefray the garlek-monger."
> PIERS PLOWMAN (C), vii. 373,

and in the compound names of fishmonger, ironmonger, etc.

We thus see that the word *fellmonger* has long been applied to an industry which entails the trafficking in the woolskins of sheep, including their subsequent dewoolling, the preparing the wool for market by assortment and drying, and the conservation of the denuded skin for sale to the leather manufacturer.

Selection of Fellmongery Site.—In selecting a site for the establishment of a fellmongery, it is of paramount importance that *the supply of water shall be unlimited, cold, and pure*, and that the *sewage arrangements* should cause no trouble to the health authorities, or that, in conducting the business, no offence is caused to the surrounding inhabitants of the district. Without the observation of these vital factors, difficulties will certainly arise.

Woolskin Supplies.—A fellmonger obtains his supplies from many sources, necessitating a subdivision into "Domestic" and "Foreign." The domestic supplies are those obtained within the country in which the fellmongery is situate, and the foreign supplies are those obtained from other countries to that in which the fellmongering is carried out, and such fellmongers are titled "Foreigners."

We thus have two distinct kinds of fellmongers, "Domestics" and "Foreigners," which will call for considerable elucidation in regard to the whole question of supplies.

In such countries as New Zealand, Australia, Argentina, including Patagonia, the United States of

North America, and Canada, the fellmongeries are controlled by firms with enormously capitalised plants, who may or may not be, in turn, sheep stock raisers, but who in all cases kill or slaughter all the sheep and lambs whose skins they dewool immediately after slaughter, and subsequently process the denuded pelt for oversea or land transport. For convenience of expression and facility of writing, these firms will be referred to in the ensuing text under the single title of "Freezing Companies."

On the continent of Europe, the system of public abattoirs is nearly everywhere established, where butchering of all animals for domestic consumption must by law be performed under proper sanitary conditions and inspection, the fellmongering being carried out by fellmongers, who buy the wool skins but do not carry out any subsequent processes, such as is the case with the freezing companies.

In Great Britain public abattoir slaughtering of animals for food is not in vogue. The so-called slaughter houses are sometimes municipal properties, in many instances very inefficiently supervised; slaughtering is in the main carried out by the butcher in the confines of his farm or place of business, and slaughtering by private individuals in the back yards of their houses is not unknown. The conditions of slaughtering animals for domestic food in these Isles require revision most strongly on hygienic principles.

The conditions under which the woolskins reach the fellmongery have undergone considerable change during the past two decades. Formerly the fellmonger or his buyer attended the local markets, bought a supply of woolskins from the butchers within a few hours after killing the sheep, and rapidly transferred them to his fellmongery, which was usually located within easy range of his source of supplies. To-day, although to a very limited extent, the fellmonger still visits the local markets, but obtains a minor portion only of his total supply direct from that source.

In the larger towns, hide and skin markets have been formed, sometimes from capital subscribed by the butchers and their friends; these markets send out their agents to secure supplies of raw hides and skins for sale by auction, at their weekly auctions. To these sales the fellmonger has to repair in order to secure his supplies, frequently buying the skins from his own district. This change incurs railway transit to and from the markets, which means that the skins will be one day in the butcher's hands, one day in transit to the market, two days at the market, and one day in transit to the fellmonger's yard, or five days before the woolskins can be handled, as against not more than two under the old order of things. As the butcher makes no effort to cure the skins, the results from putrefaction, especially during the summer months, are very deleterious to the condition of the pelts; and it is just during these summer months when the slaughter of sheep and lambs is at its height. As most domestic sheep and lambs in the British Isles are artificially fed, the skins are more tender, and the putrefactive organisms present in and on the wool, even awaiting entrance to the wool follicles immediately the conditions are ripe for them to commence their depredations; they are not slow to avail themselves of the conditions which the hot weather presents, in order to fulfil their mission of restoring the pelt to its original elements.

The Rôle of Microbes in Putrefaction.[1]—The bacteriology of putrefaction has been ably dealt with by Dr. Georges Abt of the Pasteur Institute, Paris, and published in a paper under the title, "Le rôle des microbes dans la putrefaction des peaux en poils et en tripe dans les confits" (Bull. Syndicat General, Cuirs et Peaux, Nov. 10, 1908); and subsequently by J. T. Wood in a paper, "The Bacteriology of the Leather Industry," published in the Journal of the Society of Chemical Industry, June 15, 1910. As the subject is of importance to the student, and Mr. Wood has so ably collected all the known matter on the subject in his paper, I have, by the kindness of Mr. Wood, permission to publish his paper in full with the illustrations (see Appendix). I may here, perhaps, recommend to my readers, before proceeding further, the perusal of the first part of Mr. Wood's paper.

The requisite conditions for the growth of putrefactive organisms within the sheepskins are present after slaughter, *i.e.* moisture and heat. Without humidity life cannot exist for any length of time. In fact, as Le Dantec says: "The whole history of life is bound up with that of liquid water; *life is an aquatic phenomenon.*"[1] For its development a certain amount of heat is necessary. Exactly the amount of heat required varies with different species; some bacteria only flourish and grow at temperatures below freezing point of water, such as those found in saline liquids; others at temperatures as high as 170° F. The putrefactive organisms will not survive such high temperatures as the last; on the other hand, they would not be killed but only arrested in development and activity at the lower temperature. The former feature was discovered by Lord Bacon, the great apostle of experimental philosophy. To quote literally from Macaulay's Essay on Lord Bacon: "It occurred to him (Bacon) that snow might be used with advantage for the purpose of preventing animal substances from putrefying. On a very cold day, early in the spring of the year 1626, he alighted from his coach near Highgate, in order to try the experiment. He went into a cottage, bought a fowl, and with his own hands stuffed it with snow. While thus engaged he felt a sudden chill, and was soon so much indisposed that it was impossible for him to return to Gray's Inn. The Earl of Arundel, with whom he was well acquainted, had a house at Highgate. To that house Bacon was carried. The Earl was absent; but the servants who were in charge of the place showed great respect and attention to the illustrious guest. Here, after an illness of about a week, he expired early on the morning of Easterday, 1626. His mind appears to have retained its strength and liveliness to the end.

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[1] In the Journal of the Society of Chemical Industry for October 31, 1912, there appears an interesting paper by Mr. A. M. Wright, chemist and bacteriologist to the Christ-church Meat Company of New Zealand, on the "Chemical and Bacteriological study of Fresh and Frozen New Zealand Lamb and Mutton," which is not without interest to the student.

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[1] "The Origin of Life," Professor Felix le Dantec, Sarbonne, Paris.

He did not forget the fowl which had caused his death. In the last letter that he ever wrote, with fingers which, as he said, could scarcely hold a pen, he did not omit to mention that the experiment of the snow had succeeded 'excellently well.' "

Of Lord Bacon's discovery, which ended in the sacrifice of his life, has been taken the fullest advantage by the freezing companies, who do not in all cases actually freeze the products of their factories, but only reduce the temperature of the chilling chambers and holds of the ships to a few degrees above the freezing point of water.

To carry out such a method as the freezing or chilling of hides and skins for oversea transport or for storage purposes generally is neither practicable nor desirable. The effect of freezing a wet or damp skin is to expand and rupture the fibres, resulting in very soft, spongy leather. There are but two satisfactory methods of curing hides and skins; satisfactory in the sense that putrefaction is arrested. The first and most common is to employ common salt by strewing it over the flesh side. The effect of this operation is to withdraw the free moisture, without which the putrefactive germs cannot develop. Salt is only a mild antiseptic, that is, it arrests the development and activities of such germs, but does not kill them. In applying the salt method of cure it is important that the salt should be fine ground salt, and of as pure a character as possible. Dr. Georges Abt, at the London Conference of the International Association of Leather Trades Chemists held in 1912, said that the results of his investigations into the question of salt stains in raw salted skins conclusively showed that the stains were due to certain impurities in the salt; viz. the presence of crystals of *calcium sulphate*, which were gradually converted into *calcium phosphate* by the help of splitting-up products of nucleo-proteins. Prof. Becker also illustrated salt stains which were the product of bacterial action, and which he attributed to bacterial infection, probably from the dirty conditions under which the animal had been slaughtered, or under which the skin had been salted, or had been stored. The whole question of salt stains is still *sub judice*, and the work of investigating them has been committed to an international committee.

To preserve woolskins from putrefying, it is absolutely necessary that the excess of moisture shall be withdrawn, and the activities of the putrefactive organisms arrested. This is most conveniently performed by laying a good coat of fine salt all over the flesh side, after the skin has had time to cool after slaughtering. Such skins should then be folded side to side, and allowed to remain so, until the salt has absorbed the excess of moisture. Or, if salt is not immediately available, the woolskins can be *semi-dried*—but *not fully dried*—before shipment to the local auctions.

The second method is satisfactory only so far as it completely arrests decomposition, but not in the result to the leather, viz. by drying the skin right out. Such wool skins known as "sun-dried" or "air-dried" come from overseas and are known as "foreigners."

Sometimes they have received a coat of salt before drying, which is an improvement and the most satisfactory way of treating such skins, provided they have been subsequently dried in a current of air and not in the direct rays of the sun.

If skins have to be dried out without salt, it would be an improvement if they were first washed in a bath of half per cent. solution of formic acid. This would effectually sterilise all putrefactive germs, and such skins soak back readily without the aid of putrefactive agencies. If formic acid is not available, lactic, butyric, or acetic acids may be employed, but not always with equal advantages. Failing these, sulphurous acid may be used in similar proportions.

In curing any skin intended for sale to leather manufacturers, it is of first and paramount importance that the living cells of the skin tissues be kept in a healthy condition; not killed, but only made dormant. The greatest enemy which the curer has to meet are the organisms of putrefaction, which are fortunately, or unfortunately, ubiquitous.

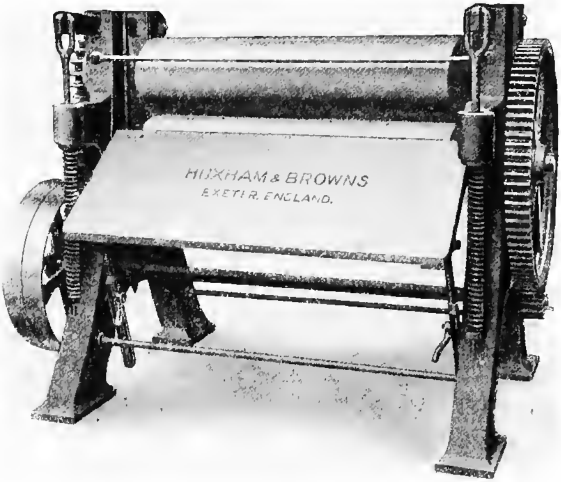
Fellmongering of "Domestics." Freezing Companies' Methods.—The flayed woolskins are permitted to cool for a few hours in order to rid them of all animal heat; then they are thrown into large pits containing cold water, and mechanically agitated by means of paddles mounted thereon. In these pits they are well washed through several changes of water; or they are introduced into large revolving drums, with open sides and having holes around the periphery; into a drum containing a suitable load of woolskins a copious flow of cold water is introduced. The fouled water flows away freely from the washing skins.

The importance of thoroughly cleansing the wool from all adhering blood, dirt, etc., in order to prepare it for the market, is fully realised by all freezing companies, but not always by some of the smaller fellmongers. If the wool is thoroughly cleansed, the risk of deductions for presence of material which is not wool is materially reduced, and a greater approximation to the full market price is obtained. If the wool is not cleansed the buyer bases the values upon his estimate of the amount of such non-wool material, which is not always satisfactory to the seller, nor always without risk to the buyer.

There prevails a general opinion among fellmongers, that the washing of woolskins is detrimental to the pelt, removing some of the "nature." Provided the pelt is not already putrefied, then no injury is done, but, if putrefaction has already set in, then the effects of such putrefaction will be washed out, to the advantage of the succeeding processes. The washing of all woolskins should be thoroughly and efficiently carried out prior to the next process, that of depilating, but, before proceeding, all the free water must be removed either by means of a hydro-extractor or by using a squeegee or wringing machine.

The system which prevails in some quarters of laying the washed and wet skins in heaps or piles and then placing weights on the top is not satisfactory, because the bottom skins are always less moist than the top skins. Regularity in the methods of all processes makes for efficiency!

Depilation.—The cleansed and partially dehydrated woolskins are now laid, wool-side down, on a very low and slightly hog-backed table, the ridge running from neck to tail. On this table (about two to three inches high) the woolskins are carefully spread, and the entire flesh side opened out. After laying the first skin down and straightening out the shanks, flanks, neck, etc., another woolskin is laid likewise on the top and opened out accordingly, and again another woolskin on top of the second, and so on until a pile about three feet high has been built. Alongside, at the head or the tail, as may be most convenient, a tub is placed to hold the depilating material. This tub should not be more than thirty



A WRINGING MACHINE FOR WOOLSKINS.

inches high and of sufficient capacity to hold a heavy charge. For each depilating table, two swabs are required; these are best made of coarse fibres of any non-keratinous material; the fibre is fastened to the end of a pole about three feet long.

The older method is to prepare a solution of milk of lime to the consistency of cream, by slaking rock lime into a putty condition in a suitable pit, where it can be stored for use as required. The modern mode is to add to the milk of lime a given amount of sodium sulphide, a useful mixture being about 25 per cent. to 30 per cent. of sodium sulphide to the weight of rock lime used, and the whole reduced to the consistency of cream. Several methods of mixing the sulphide of sodium with lime have been suggested, but they possess no advantages over the simple method of preparing the lime putty, and, the weight of putty being known, the dissolved sulphide is added to the lime putty in the depilating tub, and sufficient water added to reduce the whole to the consistency of a cream, by vigorous stirring with a wooden pole. The consistency depends entirely on the point that the depilating material shall be so thick as not to run off the skin while it is being anointed, and to contain sufficient water as will enable it to work. The active dewooling agent is the sodium sulphide and not the lime. Calcium sulphydrate is formed and is the most active, but sodium sulphydrate (in conjunction with the hydrate formed at the same time) ($Na_2S + OH_2 = NaSH + NaOH$) is also quite efficient, as is proved by using Na_2S alone. Sodium sulphide cannot be used alone without causing loss of wool, of which it is a dissolving agent, although, if it were possible to add to the solution of neat sulphide of sodium a material (unaffected by sulphide) which would reduce it to a cream consistency, there would be no great objection to its use.

The depilating material having been prepared in the tub, a man stands at each side of the pile of skins, and, with the swab, previously dipped into the depilator, carefully transfers the latter to the flesh side of the uppermost woolskin; commencing with a coat down the centre of the back and working outwards, but taking great care not to touch the wool around the edges of the skin with the depilating material. At the butt end of the pile, a third man stands ready to take the skin after painting, this he transfers to a suitable adjacent place where he lays the woolskin wool-side down; the next skin after painting is laid flesh-side down on top of the first and so alternating until a conveniently high pile has been built up. These piles are left for twenty-four hours, when the wool will be found to be ready for removing from the pelt. The whole of the foregoing operation should be performed under cover, away from the sun's rays and in as cool a place as possible.

Mr. Wood, in his paper already referred to, gives some important information in regard to the scientific aspect of depilating and liming. [*Read in Mr. Wood's paper the section on "Depilating and Liming." See Appendix.*]

Wool Pulling.—The removal of the wool from the woolskin is known as "pulling" and is conveniently

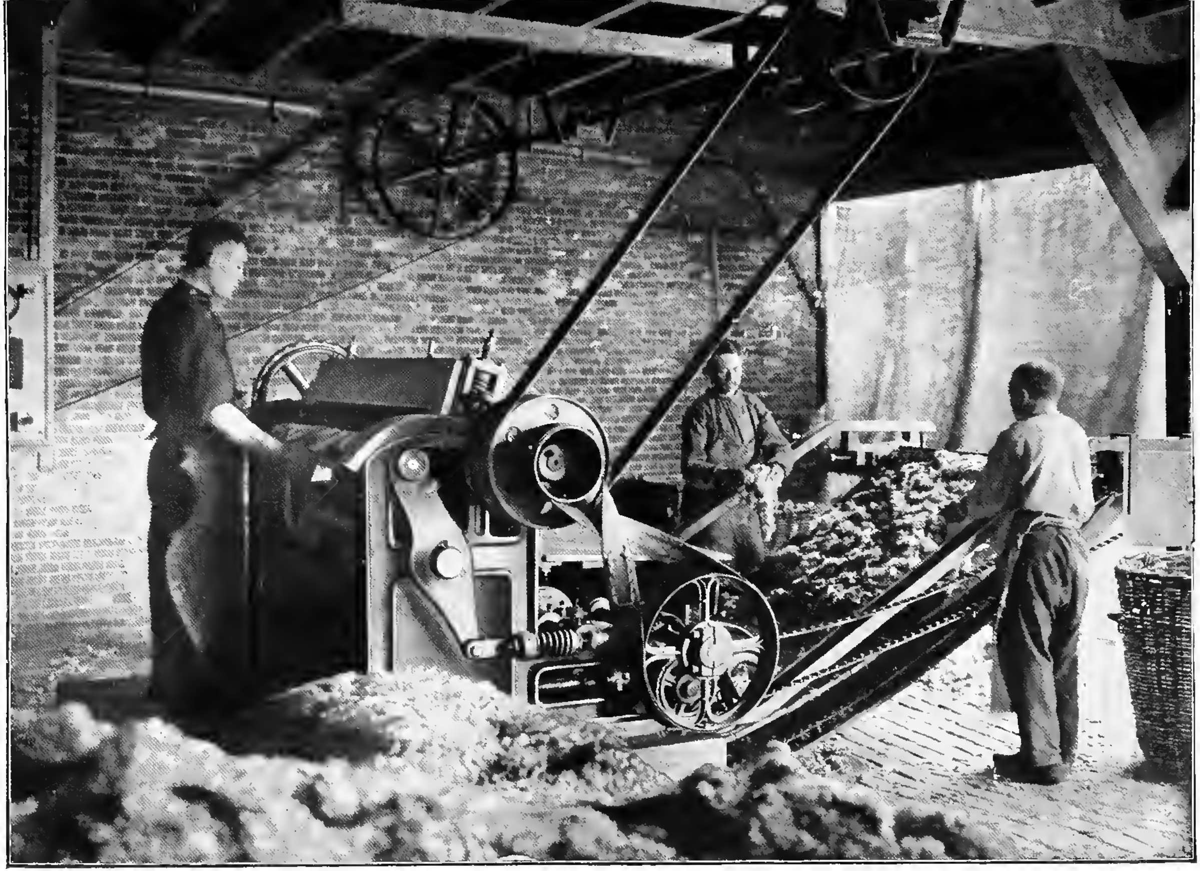


PLATE 29.

A DEWOOLING MACHINE IN OPERATION WITH SORTING TABLE.

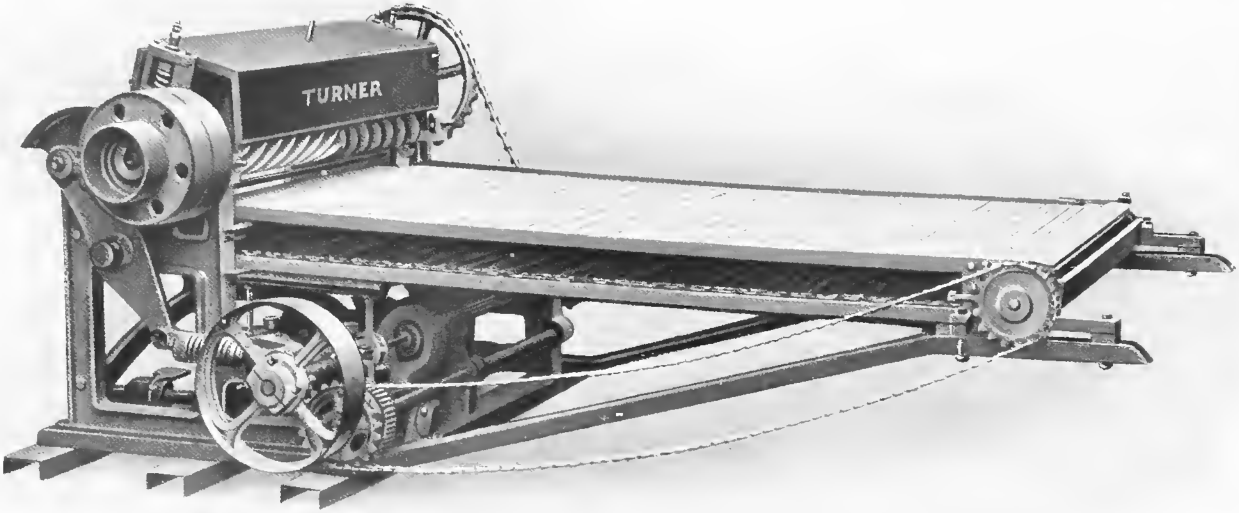


PLATE 30.

DEWOOLING MACHINE WITH SORTING DELIVERY TABLE.

performed by expert men termed "pullers," who either operate by pushing the wool off by hand over a round-faced beam, or by pulling the wool off, by laying the woolskin over the knees upon which another woolskin has been laid, flesh-side up, in order to obtain suction hold between the skins. An expert wool puller knows by experience exactly the growth of the various qualities of wool as they lie on the different parts of the skin; these selections are thrown into different bins or boxes, from which they are removed from time to time prior to the drying stove. In many large wool-pulleries, or in cases where the qualities of wool on the skin are not numerous, the pulling is performed mechanically by a machine specially constructed for the purpose, and the wool, as it is removed, is delivered on to a travelling table, alongside which two or more sorters work and rapidly sort the lesser or inferior selections of wool from the mass, as the table travels along.

It is scarcely practicable to give any adequate idea of the distribution of the classes of wool on a sheepskin, but suffice it to say that, as a rule, the highest grades of wool grow on the neck and down towards the tail, where the next quality will appear; the lowest quality being on the extremities.

Wool Drying.—If the weather is hot and dry, much of the wool may be dried out in the open on the grass, or, if it is inclement, the drying may be performed in suitable stoves having latticed floors, and heated by steam pipes or other suitable means. The employment of machines for drying wool is fast becoming the vogue, and offers advantages which do not occur under other conditions. Space is economised, but, what is of greater importance, the wool may be dried to an uniform condition, neither too dry or the reverse.

Wool Packing.—The dried and sorted wool is packed for export in bales of suitable size and weight by hydraulic pressure, care being taken in order to ensure uniformity in deliveries.

The Pelt.—The denuded woolskins are known as the "pelts," and contain considerable foreign matter; and, as they are pulled, are thrown into pits containing cold water, with paddles placed over the top of the pit, and thus, by rotation, are thoroughly washed through several changes of waters. If the water contains carbonic gas, this is precipitated, in the first washing only, by adding a bucketful of lime water before putting in the pelts; if this is not done, water blasting of the grain will be caused.

In view of the extent to which artificial feeding is carried on in the freezing companies' countries, I am of the opinion that the washing is excessive and might be reduced to one washing with advantage to the pelts and the subsequent processes.

After washing, the pelts are transferred to a paddle lime pit, containing fresh milk of lime saturated, and the pelts are paddled for some hours. Provided the agitation by paddles is confined within reasonable limits, there is no serious objection to this method, but unfortunately it is often the cause of very serious damage to the grain of the pelts. The effect of liming is to swell

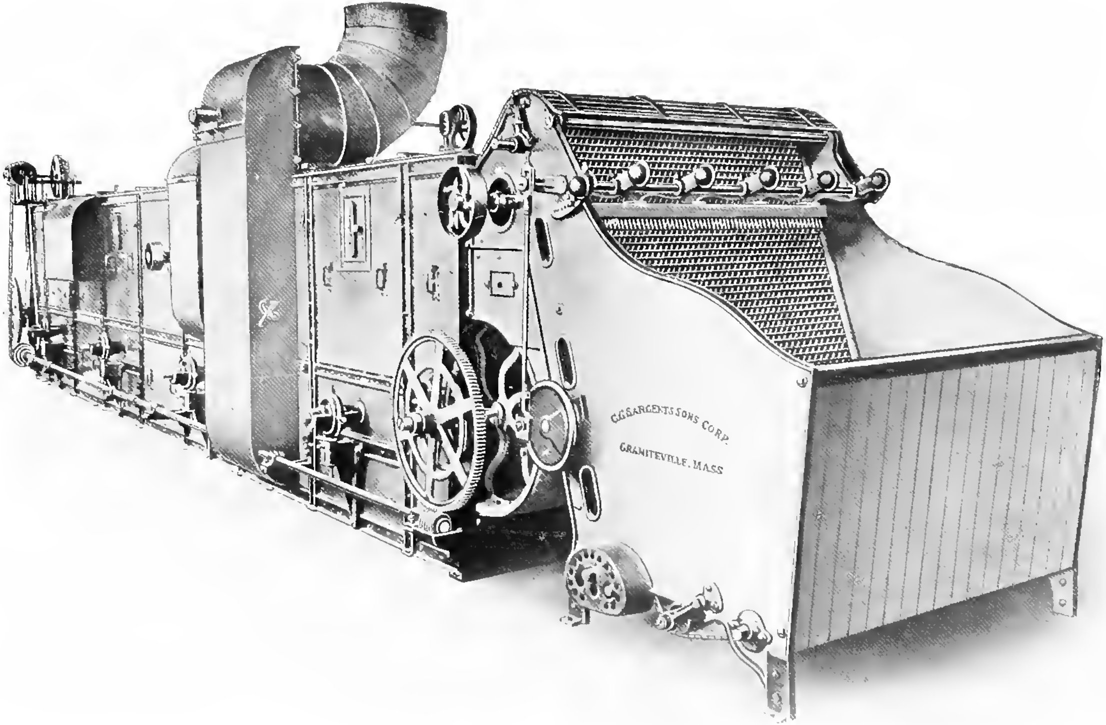


Plate 31.

FEED END OF TWO-SECTION RIGHT HAND WOOL DRYER.

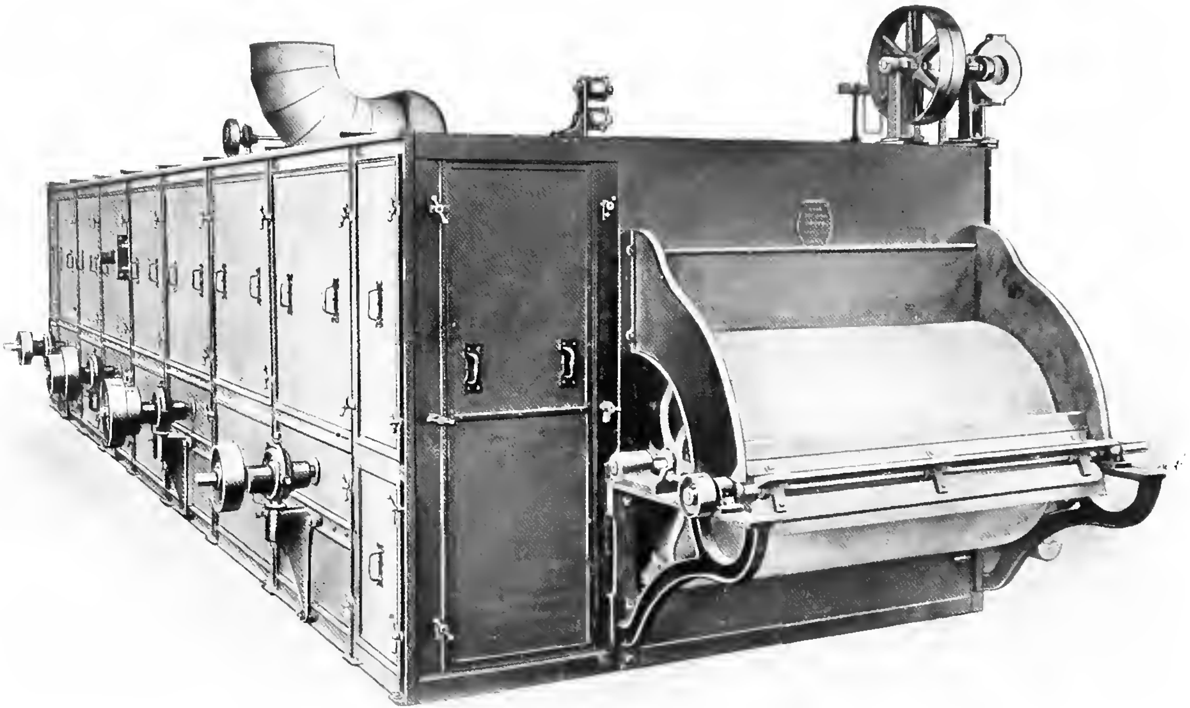


Plate 32.

DOFFER END OF TWO-SECTION RIGHT HAND WOOL DRYER.

the pelts, and such swelling of the oversea pelts, with the enormous amount of fat content, is greater than with harder and firmer pelts; the swelling causes the grain to rise into coarse nodules of varying size, like small hillocks. The lime liquor is full of grits which adhere to the flesh side of the pelts, and, as the pelts swim round, the grain side rubs against the gritty flesh side of the passing pelt, the nodules become abrased on the glassy surface, thus grinding away the pelt surface, producing a pelt which, when tanned, looks on the grain like a leopard skin. All this trouble may be avoided by remembering that the paddle is but a mechanical device to supersede hand labour; it should only be used to turn the pelts over in the pit from time to time; immediately the pelts have been turned over the paddling should cease. The amount of liming given should only be sufficient to loosen the adhering flesh tissues in order to facilitate the fleshing operation. The liming of pelts which are the result of artificial feeding should not be carried on so far as to loosen the internal tissues; they are too loose as it is, and every effort should be directed to maintaining the pelt as firm as possible.

Trimming, Fleshing, and Wet-work.—After liming, the pelts are trimmed of all adhering offal, such as the two fore shanks, the two hind flanks, the tail, head, teats, etc., which are thrown into a suitable pit for glue stock. This pit is made up with a strong solution of milk of lime and when full the glue pieces are transferred to the glue boiler. Or the glue pieces are dried in the sun or by other suitable means and then baled up by hydraulic pressure for oversea transport and sale.

Nowadays the fleshing of the pelts is accomplished in nearly every instance by machines. Before this can be done, the trimmed pelts are laid flat in piles to drain away the surplus moisture. This is done by placing the limed pelts flesh-side down on a lime-washed floor, until a suitably high pile has been built, the last pelts being laid grain-side down to prevent air blasting.

Air blasting (like water blasting) is due to the presence of carbonic acid gas in the atmosphere (or water), which, combining with the lime in the grain of the skin, forms small crystals of calcium carbonate (chalk), thus causing that peculiar disturbance of the grain, which, when once formed, is irremediable.

When the pelts have been sufficiently long in the pile to set them firm, the flesh adhering to the flesh side is removed by machinery operating a right and left-hand spiral knife cylinder, the edges of which have previously been sharpened. The removed flesh tissues contain fat and gelatine, and this by-product follows the same destination as the trimmings from off the pelts.

The fleshed pelt is delivered from the trucks to a wash pit containing cold water, which, if it contains any carbonic gas, must first be treated with a bucket of lime water to reduce the lime to chalk. In this water and in the succeeding waters the free lime is washed from the pelt. It will facilitate the washing, if the water is heated in the second instance to about 90° F.

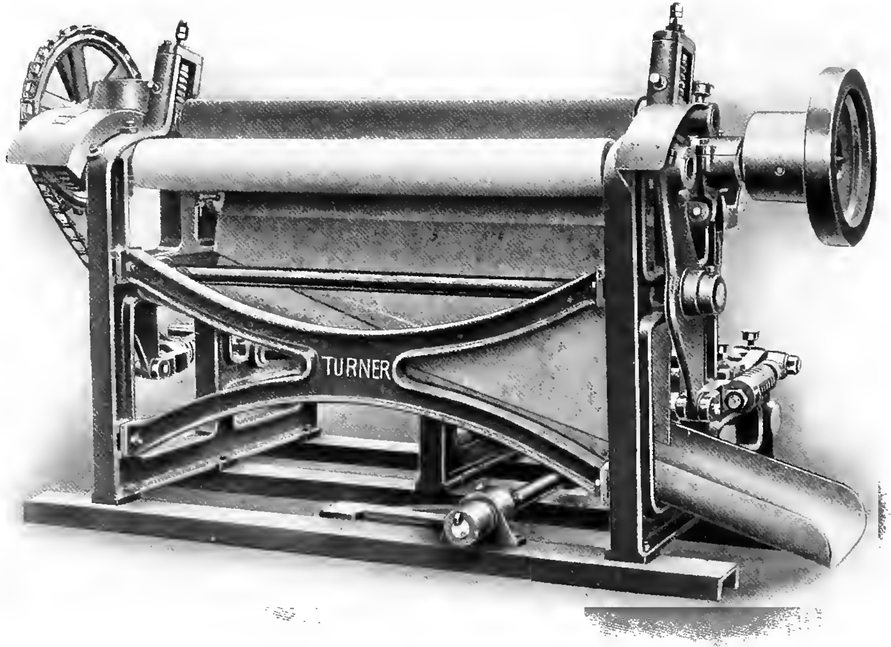


PLATE 33.

ROLLER FLESHING MACHINE FOR SHEEP-PELTS.

As all the lime is not removed by this process, it is necessary to employ chemical means to complete the removal. For this purpose there are many bates or puers offered by makers, but in most of the freezing companies the method is simplified by not carrying out the wet-work in its entirety as at leather factories, their aim and object is to perform just enough wet-work to make the pelt presentable and curable for oversea transport, leaving to the leather manufacturer the completion of the wet-work. They, therefore, as a rule do not bate the pelts at this point, but proceed to scud them by machine out of the wash-pit.

Before doing so, the washed pelts are laid down in small heaps to drain for a short while to remove excess of water. The act of scudding removes the so-called internal filth or scud, which implies the removal of any short hairs from the grain. The same machine as the fleshing machine, but with rounded edge blades of steel or slates with a sharper edge, is employed. The skins are fed into the machine grain-side to the knives, and a slight pressure is given to remove the scud.

After scudding the pelts are placed in a paddle pit containing a quantity of bran, about 150 to 200 lbs. of bran to each hundred dozen of pelts. The bran may have been previously scalded or not before making up the pit with water about blood heat. In this pit they are paddled from time to time as the necessity arises, which is indicated by the tendency of the pelts to rise to the top. Immediately one appears on the surface the whole mass is turned over by the rotating of the paddle. The period of immersion will vary from six to thirty-six hours, according to atmospheric conditions, etc. The dangers to be avoided are those which arise from excessive paddling and allowing too much gas to develop.

Considering the changes produced in the structure of the pelt due to artificial feeding, I am disposed to suggest that the processes might be amended as follows: After pulling, the pelts should be trimmed of offal, and the fleshing operation should follow on one of the modern roll-fleshing machines fitted with a grinder attachment, and the knives made of thin sheet steel backed by soft iron. The grinder will maintain a sharp cutting edge, but no wire must exist on the edge. If the edges of the knives are sharp, the pressure required to remove the flesh will be very slight, and the flesh can be removed clean without any injury to the pelt. After fleshing the pelts should be well washed in clean cold water as previously suggested, then laid down to drain prior to scudding by machine with a slate knife cylinder, and finally, after scudding, they may receive the bran-drench treatment. Provided this method is followed out, it will be seen that the pelt is prepared for its subsequent treatment by the most direct and simple processes, leaving to the manufacturer the completion of such wet-work as he may require for his special productions. Further, the risk of destruction of pelt structure is minimised.

Pickling or Rising and Falling.—In order to cure the pelts for oversea transport, pickling with (*a*) a bath of sulphuric acid solution and (*b*) falling them by means of common salt in a bath is most common. The acid "rises" or swells the pelts, and the salt bath "falls" them again in substance, the combined action going under the name of pickling.

There are many methods or deviations of the same method of utilising acid and salt for pickling, and with the object of formulating some definite system Mr. J. T. Wood[1] has written an article as follows: "The early method of 'rising' consisted in stirring the skins in a solution of sulphuric acid in water; the strength of the solution was about 1–300. In this solution the skins become swollen and gelatinous, and can be easily penetrated by the fingers. After twenty minutes they are transferred to a solution of salt, sp. g. 1·065, in which they are stirred continually, until the swelling is reduced, and the skin assumes a white appearance and is 'leathered.' This takes twenty minutes. The skins are then placed in a saturated brine, in which they fall completely. After an hour in this brine they may be drained and packed away. They will keep indefinitely in this state, and are a kind of leather. The workman, in fact, determines if the skin is properly 'rose' by pinching a fold of it between finger and thumb, when, if properly pickled, it shows a white streak like alum leather. In the modern method of rising, the skins are introduced directly into a solution containing 50 to 60 grams of common salt, and 4 to 5 grams of strong sulphuric acid per litre. This solution is in fact decinormal. In this they are paddled forty to fifty minutes, when the acidity diminishes to 40 c.c. N/1 per 100 c.c. They are afterwards transferred to saturated brine, as above described.

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[1] "The Rising or Pickling of Skins." J. T. Wood. *Tanners' Year Book*, 1912.

"Procter,[1] who has studied the process thoroughly, points out that skins may be effectively pickled with very much smaller quantities of acid than those ordinarily used. The skins are first put into a saturated brine bath, and then a calculated quantity of acid added, not exceeding 0·1 gram molecule of sulphuric acid per kilo of dry hide substance (about 100 grams acid per 100 kilos wet skin, or about 1½ ounce acid per 100 pounds wet skin). In this case the whole of the acid is absorbed. The solution must then be brought up to saturation by addition of solid salt, as the skins part with a great deal of water in the bath. This method is interesting as showing that the acid in the rising bath could in many cases be reduced with advantage, though more time would be required.

"Pickled skins must not be brought into contact with water; a drop of water accidentally sprinkled on the skins will eventually induce putrefaction, which then frequently spreads to other parts of the skin in a very extraordinary way. It certainly seems strange that putrefaction should take place in the presence of N/10 sulphuric acid, and a large quantity of salt, but the writer has found both moulds and bacteria growing in such solutions, and as soon as a growth is established, the acid is quickly neutralised by ammonia compounds produced by the bacteria, after which putrefaction pursues its normal course."

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[1] See "Notes on the Pickling Process." Prof. H. R. Procter, *Collegium.*

The method of pickling as described with sulphuric acid and salt is at least as old as the export trade in pickled skins, and has, in spite of certain disadvantages, continued down to the present day. To the principle of pickling no objection has been raised, but the use of an inorganic acid has met with severe condemnation from the Society of Arts Committee on the decay of bookbinding leathers,[1] who have clearly traced much of the decay of book leathers to the use of sulphuric acid, either as a pickle or during the process of leather manufacture.

Further, as stated by Wood, danger exists from the skins becoming sprinkled with water. As has been shown by Procter, sulphuric and other inorganic acids form more or less permanent combinations with the pelt substance, which is not possible to get rid of except by employing the use of chemicals.

For the purpose of removing the acid from pickled skins, chalk, sodium carbonate, etc., have been employed, but the element of danger is great, and the deterioration difficult to gauge. Many splitters treat the pickled skins to a lime liquor, which will form insoluble chemical compounds such as calcium sulphate, etc.

Being interested in procuring a method for easily removing all the acid from pickled stock without injury to the pelt or depreciation of the final leather, and with the view of utilising such stock for acid-free leathers, I undertook experiments about twenty years ago, which resulted in the adoption of sodium hyposulphite (a most useful salt for many purposes) as a depickler. If a pit is prepared with from 10 to 20 per cent. of hyposulphite of soda in solution, or about three to six pounds of hyposulphite to the dozen pickled skins according to size, and the skins put into the paddle pit when all is dissolved, the removal of the acid will be speedily accomplished. The acid of the skin is yielded up to decompose the hyposulphite, which, after decomposition, may be washed out, and its almost complete removal accomplished by subsequent scudding.

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[1] No. 512, pages 687–9, 1912.

Another objection to the use of an inorganic acid as a pickle is the well-known fact, also pointed out by Wood, that both bacteria and moulds will grow on the pickled skins. Those who buy pickled skins are very familiar with their state after opening the casks where such moulds have begun to grow. The common mould, *Penicillium glaucum* or green mould, is the most common type, causing stains which are almost ineradicable. The black mould, *Aspergillus niger*, has also been seen by certain observers. Some casks of pickled pelts when opened emit a foul stench, which is so sickly as to make even hardened leather workers vomit. On examination of the contents of such casks, it will be found that the outer skins of the external bundles and all the internal bundles, to which air has had access and a reasonable amount of quietude has been extended probably during a calm voyage, will be covered on the flesh side with a growth of a dark yellow to red colour, and the skins will appear eaten into holes. If one of the skins is carefully removed from the bundle, straightened

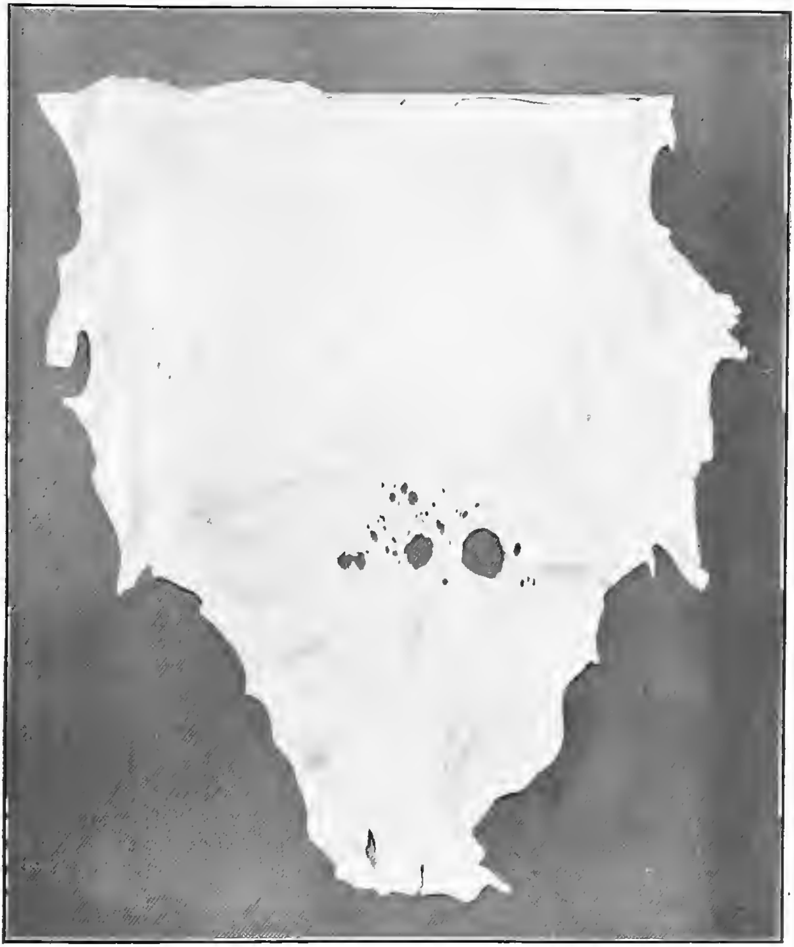

Plate 34.

A photograph of a pickled skin from New Zealand, which had been pickled with sulphuric acid and salt; showing the depredations of *B. prodigiosus* on the outside of the folded part of the bundle.

From a photograph by the author.

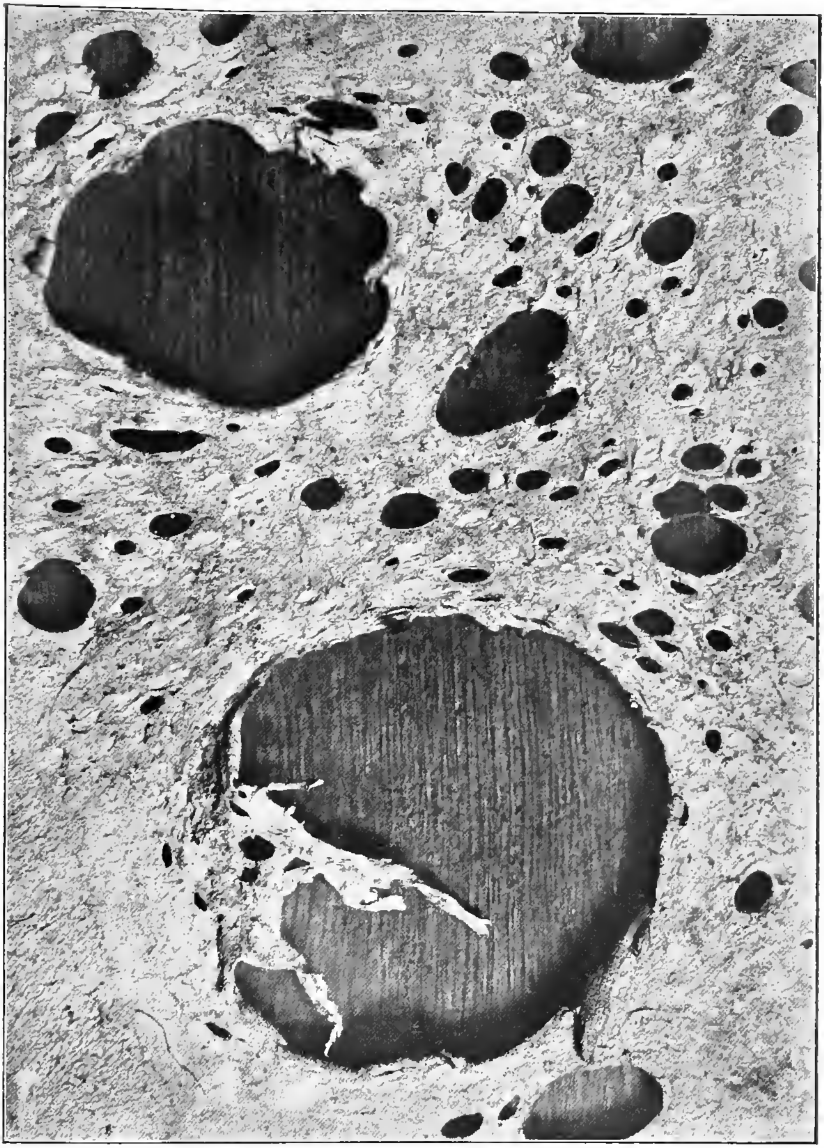

Plate 35.

A closer view of the pickled skin, Plate 34, not enlarged, but slightly smaller than the original damage as seen in the skin. The skin was photographed after tanning, it being impossible to obtain a satisfactory picture in the pickled condition.

A close inspection of this picture will illustrate the workings and depredations of the successive colonies as they appear, until the grain is finally punctured and the colony commences to attack the neighbouring skin, which in this instance the successive colonies bored through ten skins and had commenced operations on the eleventh.

From a photograph by the author.

out, and closely examined, it will be seen that the growth has commenced by eating the outer layer of the flesh, and that it has then gradually extended its operations in an ever-widening ring; but it would appear that, as the first colony extended to a given distance, another and similar colony had been born in the centre and commenced its depredations on the next layer, also widening its area of food supply like the first, and that yet another colony has begun and followed the same lines; and so on until each successive colony has eaten down in steps or slopes to the grain, which it will not eat but leave intact as a fine and delicate film. It will only puncture the grain when the final colony requires food, which it can only procure by boring through to the next skin. The neighbouring colony of germs, having exhausted its food supply, follows suit and removes the obstructing grain in order to obtain food, and so the "hole" area is extended by the successive groups as their food is exhausted. This trouble has been investigated by a Colonial bacteriologist, and I am informed that he has located *Bacillus prodigiosus* as the active agent. This bacillus is, like the mould spore, very prevalent, and it is impossible to keep it out of any factory.

The modern system of pickling with all its attendant evils has from time to time been a source of interesting discussion between Professor Procter and myself for twenty years or more, and we both felt that such evils should and would not exist, provided a method could be devised which had none of the above objections. Having had much experience in pickling, and having formed certain conclusions, I discussed them with Professor Procter, with the result that I pickled some skins in 1904, substituting formic acid for sulphuric acid.[1] That is, an organic acid was used which possessed a certain amount of disinfecting power. There were two objects to be attained by this experiment: (1) Could an acid be found which would wash out freely after pickling by using water alone, and (2) would the use of such an acid prevent the growth of fungi or bacteria? If the former was achieved, then such skins would comply with the Society of Arts Committee's conditions for use as bookbinding leathers. If the latter, then the quality of the skins could be preserved indefinitely.

A quantity of sheep pelts were taken and treated to a bath of 0·25 per cent. of formic acid until they had swollen in accordance with the ordinary conditions as described, which they will do in twelve to twenty-four hours, and were then submitted to a bath of saturated salt. After draining, one half of the whole were placed in a box which had the joints left slightly open, in order to permit ingress of any spores or bacteria while in transit. The other half of the whole were likewise boxed up but kept at Wrexham, but before boxing they were strewn with mould spores and stored in a place calculated to develop the spores. The first lot were shipped to Manaos, on the river Amazon, a town about one thousand miles inland, to which the steamer plied. This journey was selected because the steamer would have to cross the equator twice and steam alongside the equator for some days up the fever-stricken Amazon river. The whole conditions were conducive to the production of the growths of any organisms such as have been described. The box was transported as part of the general cargo, and dumped on the dock at Manaos, then reloaded and brought back to London. On arrival, they were inspected along with the second parcel by many persons. *They were pronounced to be absolutely sound and as fresh as they were at the time of shipment, the preservation was perfect.* The skins were then washed free from pickle with water, and, when tanned, were found to resemble fresh-tanned stock. This experiment has been repeated by others with equal success, the goods being shipped across the world and arriving in a sound condition, thus confirming the result of the initial experiment.

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[1] "Improved method of Pickling." The author, *Collegium*, 1904.

The objection raised against this method is that a longer time of immersion in the acid is necessary than by the present sulphuric acid process, where the rising is usually carried out in some twenty minutes. The speed of rising a pelt is in proportion to the strength of acid used in the solution. The greater the concentration of acid the more rapid the rising, the less the concentration the longer the time required to rise. The employment of an acid is to make the skins water hungry. As pointed out by the author in this experiment and confirmed by Prof. Procter's published work,[1] all picklers invariably employ too strong an acid solution. Pickling to be perfect must be given a longer time in a weaker acid bath. It is assumed that pickling, like many other rapid reactions within the tannery, is a rapid method of pelt conservation, which is true in a measure when compared with other processes; but more good pelt matter is spoilt by this assumption than the results can in any way justify. The pickler who values his stock and his reputation will seriously consider the advisability of reducing the amount of acid at present employed and give the operation more time; if he does, he will command far better prices for his pickled goods.

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[1] See "Note on the Pickling Process." Prof. H. R. Procter, *Collegium*, No. 512, pages 687–9, 1912.

With formic acid at its present price the cost compares favourably with the older method; at the same time it offers all the advantages which are or can be offered by fresh market pelts. The organic acid does not form any permanent combination with the pelt substance, and is easily removed, after salting, with water, thus enabling the tanner to produce stock, acid free. If, as in the United States of North America where all the skins are tanned in the pickled condition, it is desired to continue the method of so tanning, then there is nothing in the formic acid method of pickle which will not harmonise with those conditions. The method opens a new field for the tanner who may desire to tan acid free, or with pickle. The freezing companies are quite ready to supply such stock on demand.

Fellmongering "Foreigners."— The fellmongeries which confine themselves to fellmongering "Foreigners" or oversea dried or salt dried woolskins, are scattered all over the white countries of the Northern

Hemisphere. The largest centre is undoubtedly the district of Mazemet (Tarn), France, where more than 25 millions of woolskins are depilated annually, all, except about one million, being imported skins. In Russia there are large fellmongeries which pull, almost exclusively, dried woolskins from Siberia, a type of woolskin which fortunately does not seem to be exported. The use of the word "fortunately" will be explained later.

Foreigners are usually offered for sale by public auction, or are purchased by contract through agents in the country of origin. They are shipped in bales (hydraulic pressed) of convenient dimensions, each skin being so folded as not to injure the fibre more than is absolutely necessary. Such woolskins, after flaying, do not pass through any washing process (except in rare instances), but, after cooling, are either exposed to the weather and sun to dry, or are dried in air currents under cover, or they may receive a coating of salt on the flesh prior to drying.

To air drying or salt drying no serious objection can be raised when it is rationally performed, but the drying of woolskins by exposure to the direct rays of tropical or sub-tropical sun is to be strongly condemned. The sun's rays are extremely powerful under such conditions, the result on the sheepskin is a skin blister, which is not detectable until the woolskin has passed through the pullery and has been received at the tannery. The exposure of the flesh side of any skin to the direct rays of the sun causes the exterior to dry rapidly and case-harden, thus preventing the interior moisture from finding egress, with the result that the internal temperature rises, especially in the fatty layer, to such a height that dissolution of the delicate areolar and adiposed tissues is rapidly effected, with the consequence that the affected area separates into a blister, which, during the process of drying, gradually glues together, and cannot be detected until subsequent processes have been reached. This form of injury is not confined to dry woolskins but may be seen in salt-dried woolskins which have been subjected to like treatment. An improvement would be effected if the woolskins were first washed and then pickled by the formic acid method prior to air drying.

It is important to remind the reader that the cells of the skin tissues should (as previously stated) be maintained in a healthy condition, and this can only be done by avoiding exposure to the rays of the sun and applying a rational method of cure, and subsequent drying in an air current as cool and dry as possible; to obtain which in the countries from which foreigners are exported is no serious difficulty.

Woolskins as Carriers of Disease.—Woolskins in all conditions of cure, but more especially in the dried condition, are known conveyers of disease to human beings. The anthrax disease, so common in some, especially Eastern, countries, is too well known to require detailed description. I have elsewhere said that, fortunately or unfortunately, the dried woolskins from Siberia are not largely exported to Europe, but are in the main arrested by the fellmongeries of European Russia.

In 1892 I was called in by the Moscow authorities to investigate outbreaks of "Siberian Plague" at certain fellmongeries, the death-rate from which was abnormally high. The description of one fellmongery is typical of all such institutions I visited. The woolskins were imported in the dry state from various districts of Siberia; after a rough assortment they were soaked in a stale soak, the virtues of which lay in the fact that the soak had never been cleaned out within the memory of living man. As the soak water evaporated or was absorbed by the woolskins, it was added to by addition of fresh water, in an almost equally stagnant condition. The stench from such a pit may be imagined but not described. The woolskins were then staled or sweated in stoves (described on p. 272), then removed to the pullery. At the period of my visit it was mid-winter, the temperature being about 50 degrees of frost Fahrenheit. Every aperture which could admit air into any of the workshops had been very carefully sealed, and the rooms were heated in various ways. The outer door to the pullery had cloth nailed around the edges to exclude the cold, and, after passing the first door, another door had to be opened which had been likewise similarly clothed. The opening of the first door gave pronounced indications of what one was to expect, but the outrush of the hot and fœtid atmosphere of the room from the second absolutely beggars description. In a lifetime of various experiences in different parts of the world, I have met with many effluvia, but the stench which rose to greet me on that occasion is beyond any one's ability to detail. The scene inside the room appeared chaotic. Seated on low stools were women pulling the sweated woolskins over the knees, while at their feet were the wool receptacles. The denuded pelts were thrown over poles behind, where they lay in heaps, and were not removed until the close of the day. The plague was affecting these women, and, at the time of my visit, the deaths numbered several per week. In wool-pulling, as is well known, sores are produced at the ends of the fingers of the pullers; of such sores I saw several, and was later in a position myself to confirm by direct culture, and by inoculation of animals by others, that the Siberian Plague was identical with anthrax. Had such skins been exported to the European fellmongers of foreign skins, the ravages of anthrax in the West would have been far greater than it has been in the past.

Having given a lifetime of study to the incidence and prophylaxis of disease as conveyed by the skins of animals, I have evolved a process, now known as the "formic-mercury process," for restoring the dried skins to the wet salted condition, and the complete sterilisation thereof.[1] Had the skins from Siberia been treated with that method (assuming it was then known), the Siberian Plague would never have been heard of.

The application of the formic-mercury process to woolskins should follow the ensuing course: After slaughter the woolskins should be well washed, as performed by the freezing companies and already described; or, if this is impracticable, the simple immersion of the unwashed woolskin will suffice, provided the following conditions are complied with :—

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[1] For fuller particulars see the brochure published by Bradbury, Agnew and Co., London, entitled "The Seymour-Jones Anthrax Sterilisation Method" or Formic-mercury process of sterilisation. Copies may be obtained free from the author.

The pit should, for convenience of handling, be mounted with a paddle. The bottom, sides, and the wooden paddle must be first coated with repeated coats of boiled oil, until no further absorption takes place; or painted with two or more coats of paint, or several coats of varnish. Pits treated thus can be utilised for almost any operation of a non-alkaline character. The volume of water required to float the woolskins must previously be ascertained; this being known, then run in sufficient cold water, and add to it enough formic acid to make a half per cent. solution (formic acid of 90 per cent.); further add *one part per five thousand of the solution of mercuric-chloride.* This should have been previously dissolved by boiling. Throw the woolskins rapidly into this solution, and agitate from ten to twenty minutes; allow to rest, and agitate occasionally or until such time as the skins show signs of being sufficiently swollen but not vamped nor bloated. This may take from an hour or more according to the temperature of the solution. Transfer the woolskins from this bath to a similar pit containing saturated salt, with sufficient salt on the bottom to replace that taken up by the skins. In this pit they may be left until the skins are leathered, which takes place in course of half an hour or so.

That is the process of sterilising, and synchronises with that of pickling, except that mercuric-chloride is added in infinitesimal quantities. If the temperature of the cold water of the first pit is higher at one season of the year than at another, then the higher temperature will make for increased efficiency in sterilisation. Such woolskins can subsequently be drained and dried in an air current, and, if necessary, when the excess of moisture has evaporated out of the pelt, the woolskins may, without injury, be finally dried in the sun before packing.

If the woolskins have been previously dried then it is necessary to allow them to soak over night before paddling, in which case the time of paddling may be reduced to a few minutes. As a rule the skins will soften in a few hours, but should be watched. The operation then follows the same lines, *i.e.* well wash before painting or sweating.

The adoption of this method will remove all deleterious organisms; the sterilisation is complete, and the danger of infection from such woolskins is removed, the resulting woolskin commanding an increased value. It is not necessary to introduce the mercuric chloride in those countries where disease is non-existent. The cost of carrying out the operation amounts to a fraction of one penny per woolskin. The formic mercury method of sterilisation and cure does not interfere with the succeeding operations through which the skin may have to go, as it is easily removed by washing with water.

Sun-dried or Air-dried Woolskins.—On opening the bales at the fellmongery, they are thrown into pits containing clean cold water, in which they remain until the pelt is softened. If they do not "come to" (soften) rapidly, then the water should be changed in order to prevent the accumulation of putrefactive organisms, and decomposition of the pelt. These changes of water may be accomplished, without removing the woolskins from the pit, by providing the pit with two upright perforated boards at right angles to the corner in which the plug hole is situated.

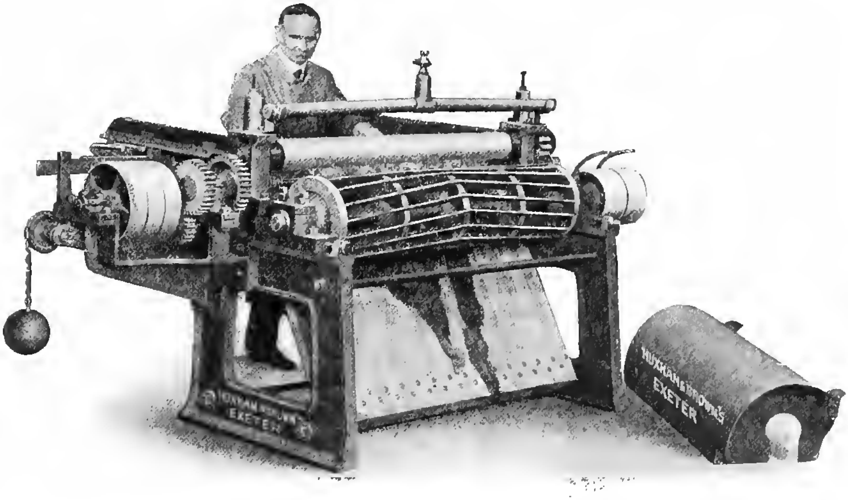
The softening of this class of dried skin may be facilitated by adding to the water (provided the pit has been protected by boiled oil, etc., as already detailed) about 0·2 per cent. of any organic acid, formic acid by preference. The employment of such an acid will prevent the germs of putrefaction operating, and the resulting pelt will be maintained in a healthier condition.

The use of organic acids in the leather industry is worth greater attention than it receives. It has long been known that all organic acids have a deterrent effect upon the growth of such life, be it animal or vegetable, as we may reasonably call "enemies." In this respect I have found formic acid to possess the strongest powers of sterilisation. It is difficult to say exactly how it is so, but one may theorise. All life, more or less, depends upon oxygen for its existence, whether derived from the atmosphere or from the medium in which it lives. It is possible, yet requires scientific proof, that such germs as are termed "enemies" to pelt matter absorb from the organic acid one atom of oxygen from the molecule of the acid present; if the hypothesis is correct, then the resulting molecule will be the aldehyde of that acid, which, as is well known, has the power of hardening gelatinous matter, and, in this respect, formic aldehyde is the strongest. On the other hand, the sterilisation may be due to the swelling power of the acid, as pointed out by Procter, or possibly its disinfecting power may be due to the presence of the CHO (the aldehyde) group, which is not present as such in any other simple acid.

Dry-salted Woolskins.—This class of woolskin softens back to the original pelt condition with greater rapidity than is the case with the sun-dried woolskins. The principal object to be attained is the entire removal of all salt, and to do this efficiently the skins should be washed through several waters, which may be done with advantage in an open-work drum following the lines described on page 327.

Washing and Burring.—The sun-dried, air-dried, and dry-salted woolskins now follow the same course. Assuming that the woolskins have been properly treated in the soaking process, restoring them to the original fresh slaughtered condition, they are now submitted to treatment in a "Straiton" burring machine, to thoroughly cleanse the wool of dirt, etc., and remove any burrs which may be adhering.

The Straiton burring machine consists of a series of mechanically operated rolls which act as a feed table, being made to feed forward or reverse at the will of the operator. Beyond the rolls is a spirally bladed knife cylinder, the blades radiating outwards from the centre, and revolving downwards and working the woolskin outwards. When the wet woolskin is laid wool side upwards upon the moving roll table, and fed towards the knife cylinder, it passes under the knife cylinder which receives its pressure from beneath. Over the skin and close to the knife cylinder is a copious stream of cold water issuing from jets in a horizontal pipe; the effect is to douche the woolskin with a constant stream of water before it enters under the scouring knife blades, and so facilitate the removal of dirt, etc. If the woolskin is not cleansed to the operator's satisfaction at the first entry, then the operation is repeated until satisfaction is secured. The first operation only accomplishes the cleansing of half of the woolskin,



STRAITON BURRING MACHINE.

which must be reversed and the other half submitted to like treatment.

The waste water flowing from the burring machine should pass over a close grid or sieve before entering the sewer in order to arrest the wool, which may, from causes of putrefaction or otherwise, have become loosened and removed by the machine. Further, the burrs will have wool adhering to them which may be subsequently removed by hand for sale.

The burring machine also performs another important operation, *i.e.* by breaking over the woolskin, or stretching the pelt and thereby preparing it for the successful accomplishment of the succeeding operations, viz. the removal of the wool by "sweating" or "staling."

Water Extraction from the Woolskins.—Before it is possible to proceed with the sweating process, it is necessary to remove as much water as possible from the wool. This may be done by placing the wet woolskins in a hydro-extractor, or by passing them through a pair of rollers.

"Sweating" or "Staling" Woolskins.—The method of sweating or staling the damp woolskin, in order to facilitate the removal of the wool from the pelt, is probably the most ancient mode of depilation, and was without doubt observed by early prehistoric man, and so employed by him; it survives until this day, but some elements of scientific control have been introduced. The process, while good for the wool, is objectionable on account of the injury it causes to the pelt. It destroys most effectually all the living cells of the skin, thus producing a pelt which is not so desirable as those which have been depilated by means of milk of lime and sodium sulphide. The operation is carried out in large buildings, either built above the ground or partly submerged, by what are known as the "Cold sweating" or the "Warm sweating" processes. A vault or pit or building is made with double walls or walls of such thickness as to maintain an even temperature internally. At each end are double doors of suitable dimensions opening outwards. The roof has suitable apertures which may be opened or closed at will. The floor is drained with suitable channels and the grids are trapped. In the case of warm sweating, steam pipes or hot-water pipes are distributed in such a manner as to maintain a regular temperature. At given distances along the floor, openings are provided with doors to admit air when required. At a convenient height, rails of wood are placed laterally, with tenter hooks in them upon which the woolskins are hung by the head. The internal atmosphere will be moist from the wet woolskins, and, in modern sweating stoves, the temperature will vary from 15° to 20° C.

The foreman in charge of the stove will, after a few days, examine the woolskins by pulling the wool in the upper regions of each skin, and if it is easily removed, he tries it in the bottom, and if it pulls freely he drops the woolskin on the floor for removal to the wool pullery, but if it pulls only in the neck and not the butt, then he takes the woolskin down and rehangs it with the tail to the hooks. The whole operation is finally completed in about five days. The depilation is the result of bacterial action, (see Mr. Wood's paper. —Appendix).

In the town and district of Mazamet (Tarn), France, where, as stated above, more than 25,000,000 woolskins are depilated annually, sweating is largely carried on, but the fellmongers are gradually turning their attention to depilating by means of milk of lime and sodium sulphide, because of the simplicity of the operation, less cost, and improvement in wool and pelt.

Woolpulling.—This follows the lines already described on page 239 ; also drying, etc.

Fellmongering British Domestic Woolskins.—The *modus operandi* followed by the British fellmonger does not in all instances coincide with that of the freezing companies, already described.

The British fellmonger labours under many disadvantages as compared with the firms who kill their own sheep and fellmonger the woolskins. He has to attend at the weekly auction markets and buy his supply of woolskins in the condition in which he may find them. Such woolskins, although classed in a limited manner as to age and wool, are not classed as to the condition of the pelt, which may be badly flayed and in an advanced state of putrefaction.

In this section, I purpose to criticise the whole of the British methods of butchering and fellmongering with the hope that reform may ensue, in the interests of public health and the leather industry. The recommendations made are not novel, except to the average Britisher. They are the most approved methods which are in force in every other country except Great Britain.

Flaying Woolskins.—It is well within the truth to say that at least seventy-five per cent. of the woolskins flayed within the British Isles are flayed by butchers who are known as private slaughterers. In the country districts, where the bulk of sheep are killed, the butcher is usually the farm hand and has never been instructed in the art of killing or flaying, with the result that the flaying of sheepskins (Scotland and Dublin county excepted) is the very worst in the world. It has been well said by such large butchers as Alderman Stephenson, Liverpool, the President of the Meat Traders' Association, that it is not necessary for any man to use a knife in flaying a sheepskin after he has opened the carcase ; it should be elbowed off while it is yet warm and the skin is ready to part from the carcase. The present disgraceful state of affairs can only be remedied by introducing technical instructors in killing and flaying by the various County Councils, and it is for the Fellmongers' and Light Leather Federations to take the matter up. The Board of Education have already given their sanction to the installation of such instructors by County Councils under their schemes of Higher Education.

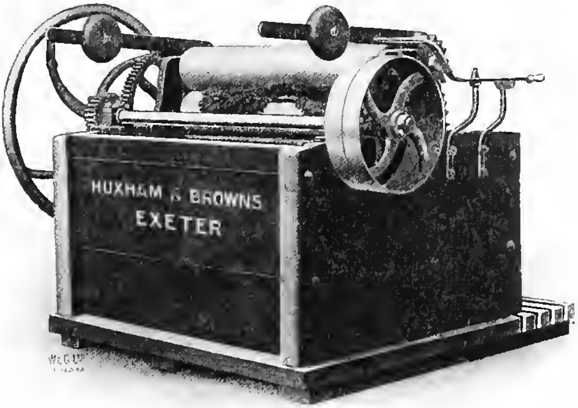
While the woolskin is being flayed by elbowing off, which may be assisted by blowing air under the skin before the skin is cut, provision should be made for the flayed woolskin to drop into a receptacle, in order to prevent contamination with blood and dirt. As soon as flayed, it must be removed to a suitably cool place to cool, and subsequently salted as already described. In this salted condition it will survive the transit to and from the auction mart to the fellmongery (see Mr. Wood's paper—Appendix).

With a proper method of cure, there can be very little objection from the point of public health.

At the Fellmongery.—The woolskins are at once plunged into clean cold water, usually in pits, in which they are allowed to soak, and are handled by polès with a cow's horn fixed to the end. This method is not as satisfactory as that followed by the freezing companies and described on page 230. Some fellmongeries are too small to afford washing machines, but have an excellent supply of cold water from the stream running through the yard, into which the woolskins are thrown ; a dam having been first built to retain the water in a shallow pool. This may be very useful to the fish, but is insanitary and not entirely satisfactory to conditioning the wool. Woolskins under all circumstances should never be allowed to rest until they are ready for applying the dèpilating mixture.

Some of the larger fellmongers are fully alive to the advantages to be derived from a thorough washing of the woolskins in order to cleanse and prepare the wool for market ; they either wash the woolskins as the freezing companies do, or they employ a long trough, through which the woolskins are conveyed by a suitable arrangement of bands working against a flowing stream of cold water. At given distances along the trough are pairs of rollers, through which the wet woolskins pass in order to express the dirt and blood ; the woolskins being delivered from the trough through a final pair of rolls which are not in the water, and so the woolskins are freed from excess of water. Reference has been made elsewhere (p. 231) to the washing of woolskins and its effect on the pelt.

If the blood has dried very hard on the woolskin, then it may be necessary to remove it, also any adhering dung, by subsequent working over a wooden beam with a sharp knife, or by cutting off the dung. It is very rare to see the feet (trotters) left on woolskins at the present day; if there are any they must be cut off before washing. It is usual for the shepherd to remove the tail from the lamb soon after birth, but, if this is not done, then that appendage must be likewise cut off, and the wool removed by staling.



A WASHING AND WRINGING MACHINE FOR WOOLSKINS.

Depilating.—The correct and most approved method of depilating woolskins has been detailed on page 232, but unfortunately many British fellmongers are not alive to the advantages of following such approved operations, and continue to use milk of lime alone. Mr. Howard Priestman[1] has interested himself in this phase of the subject and written much on the matter, and he points out that skin wools from pelts depilated with milk of lime alone are of lower value than wool from skins depilated with sodium sulphide and lime. Milk of lime will not remove the wool without the aid of bacterial action (see Mr. Wood's paper—Appendix).

After the wool has become loosened, some fellmongers open the woolskin and throw it over a horn pole and draw it through water to wash off the surplus lime adhering to the flesh. This is one of the prime causes of the injury to the wool from the depilating material. It is done for the convenience of the puller, but should be forbidden.

Wool Drying, etc.—This has already been dealt with on page 239.

Shearlings.—An early shearling, that is the skin from a sheep which has just been shorn and the wool is short, has a greater pelt value than a wool value, hence it receives a different treatment.

After washing to remove adhering blood, etc., shearlings are painted with milk of lime only, and immersed in a shallow pit, the skins being laid flesh to flesh and built up in piles. Into this pit cold water is run, and the skins left until the wool rubs off freely. The wool is removed by rubbing with a suitable wooden tool or rounded edged knife. By following this method of depilation the skins feed and appear finer for the purposes of splitting.

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[1] "Skin Wools: their Varieties and Characteristics." Howard Priestman.

Making Shearlings.—In some fellmongeries it has been found to pay to shear off the long wool with one of the mechanical shearers by placing the woolskins flesh-side down stretched out over a flat table, and shearing the fleece off. This of course entails a certain loss of wool, nevertheless it has its votaries.

Pelt Treatment.—In the British Isles the rule is, after denuding the woolskin, to allow the pelts to accumulate in the pulling shop until the day's work is done, and then transfer them to what is called a gathering lime. As the pelts are already in a state of incipient decay, this should not be permitted; they should be removed with greater frequency from the atmosphere of the pullery.

The gathering lime is usually an old or weak lime liquor, in which pelts have for some time past been gathered awaiting the advent of the pelt sorter. The lime-pit may or may not be recharged with fresh rock lime or lime putty, but in regard to this no regularity prevails.

The pelt sorter is the representative of the leather manufacturer by whom he is paid, and his duty is to classify the gathered pelts, as between both parties, which rôle has been honourably performed with satisfaction for many years.

After the classification is complete, the pelts are carted off to the railway and dumped into railway trucks. Before doing so some care is taken to strew straw over the bottom of the trucks, on which the bottom skins are laid flesh side down, and similar skins are laid flesh side to the sides of the truck. The bulk is then dumped into the truck, and finally covered over with pelts flesh-side out; a tarpaulin being finally stretched over the truck to protect them from the elements. Some leather manufacturers supply limed sheets to spread over the trucks before entering the pelts, and to cover them over finally.

Criticism of the Gathering Lime, with Suggestions for Improvement.[1]—It has already been pointed out by the author, and confirmed by Wood and Trotman,[2] that the fellmonger's gathering lime is one of the main sources of damage to the pelt. The gathering lime is an old institution, and one which has escaped the vigilance of the scientifically inclined tanner. The author gave much attention to this question for some years and arrived at the conclusion, after repeated tests and observations, that the cause of "looseness" of the fatty layer (*panniculus adiposus*) was primarily caused by the want of proper cure of the woolskin by the flayer and the subsequent obsolete and antiquated methods of conservation within the fellmongery, especially in the continuance of the use of gathering limes. A great many fellmongeries were visited and samples of the gathering pits analysed as follows: Filter through common filter paper or cotton wool, 50 c.c. of the gathering lime liquor into a 100 c.c. cylinder, add 10 c.c.

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[1] The author went very thoroughly into this question in the spring of 1900, and published his results in the *Leather Trades Review*. See "Looseness or Slackness in Sheepskins," and "Further observations on Looseness and other Sheepskin Faults."

[2] "The amount of Skin Substance dissolved in Fellmongers' collecting Limes." Wood and Trotman. This research was the outcome of the author's two articles on the same subject.

of glacial acetic acid and fill up the cylinder to the 100 c.c. mark with saturated solution of common salt; the dissolved pelt substance will float rapidly to the top, and, for convenience of comparison with other tests, it should be allowed to stand for an hour, then the depth of the thickness of dissolved pelt substance can be read off in degrees c.c.[1] Wood and Trotman suggest employing hydrochloric acid for acetic, as showing more dissolved pelt substance.

Following out this simple method of limeyard control in many of the fellmongeries visited, I obtained the most astounding results. In no case was a single gathering lime free from an excess of dissolved pelt substance, while in several the amount was so large that it was difficult to filter the liquor. At one yard it took two hours to obtain 10 c.c. of filtered liquor and on adding the acetic acid and filling up with salt solution, the 10 c.c. of gathering lime liquor stood as an almost solid mass of flocculent skin precipitate filling the entire cylinder. It is scarcely necessary to say that the fellmonger admitted that he never remembered the pit ever having been cleaned out, nor did his father ever clean it out. This was not an isolated case; I met with three in two weeks on one journey.

To my mind, there can be no doubt that the conditions, as they existed at the time of my visit, were the outcome, in a large measure, of the altered conditions of feeding sheep during the past three decades, which had accentuated the mischief.

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[1] The salting out of gelatine is an old idea, but its application to limeyard liquor control, on the lines indicated, was first introduced to the author's notice by Mr. E. Munro Payne.

The evil commences with the want of care by the flayer of the woolskins, putrefactive bacteria get a hold which they never release, and which the subsequent operations do not sterilise; the depilating operation with milk of lime alone mainly relies on the activity of such organisms (see Mr. Wood's paper—Appendix). They are carried into an agreeable medium for their growth—the gathering limes—where they rapidly attack the pelt, and during the process digest and dissolve the tissues, especially those which show the least resistance—the areolar tissues—in the fatty layer, thus producing the looseness referred to.

An improvement may be easily effected by thoroughly washing the pelts as they come from the fellmongery, and freeing them, by repeated washings with cold water, of the organisms of putrefaction, before placing them in a lime liquor.

Wood and Trotman recommend the following limits for a lime in which pelts are collected. "Lime in solution not to be less than 0·1 gram of CaO per 100 c.c. The alkalinity should not exceed 6 c.c. N/1 per 100 c.c. To attain this standard, the pelts would require to be well washed in clean water after pulling, and the lime pit cleaned out and renewed after two lots of pelts have been put through."

By permitting the pelts to lie about, waiting to be thrown into the gathering limes, severe air blasting on the grain is frequently caused, due to the atmospheric carbonic gas forming crystals of chalk, by combination with the lime in the grain. This mischief is found in all limed pelts which have been exposed to the atmosphere for some time. It is accentuated during the transmission of the pelts to the railway, during dumping and the waiting period between the arrival of each lot of pelts, during the railroad transit, during the unloading, and so on. Besides these faults, the system of conserving pelts by liming produces many defects, such as lime specks (see Mr. Wood's paper—Appendix), truck stains, straw stains, putrefaction, sun-scorching in summer and freezing in winter.

Great Britain is the only country where the valuable raw material of the sheepskin tanner is carried in such a crude manner. If limed pelts are carried by rail in the United States, they are always carried packed in casks, neatly bundled to prevent lime creases. The depreciation caused by the antiquated methods of Great Britain requires serious consideration and revision.

In Holland, depilating by means of sodium sulphide is the vogue, and I am informed that, after the operation, the pelts are well salted for transit and resale purposes.

In the Antipodes and the Americas, the denuded pelt undergoes a cure already described. From the Britisher's standpoint, the only objection to such a treatment is the use of an *inorganic* acid, and his want of familiarity with the results of subsequent treatment in his tannery. In favour of adopting some similar change, I would point out that the bulk of the white races could employ such methods with financial success.

I make the suggestions as set out below for the serious consideration of all engaged in the fellmongering and leather manufacturing industries which would have the following advantages if adopted :—

No wastage of skin substance.

No air blasting, or other grain damages.

No frost or sun damage.

No truck stains.

No over-limed pelts.

The pelts will be received in a condition comparable with home fellmongered pelts.

Less cost in transit charges.

The fellmonger can hold his pelts until markets are favourable.

The buyer can hold the stock until such times as may be convenient, or take from such stock the qualities most in immediate demand.

Suggested methods.—The Fellmongers' and Light Leather Trade Federations should negotiate for a proper system of cure by the butcher prior to shipment to auction ; in this movement the Federation of Hide and Skin Markets should co-operate.

In the fellmongery, sodium sulphide and milk of lime should be adopted as the depilating mixture.

Denuded pelts should be removed frequently from the pulling shop, and placed in clean cold water until a sufficient number has accumulated for the day's washing, which should be performed in paddle pits or drums, as already described on page 230.

The pelts should be trimmed of offal and very lightly fleshed to remove adhering fat only ; then placed in a bath of 0·25 per cent. of formic acid (90 per cent.) solution until they have absorbed all the acid, or are slightly swollen but not vamped or bloated. The cost may be reduced by giving them a first bath of 0·5 per cent. hydrochloric acid or by mixing the hydrochloric acid in equal parts with formic acid, and then giving 0·25 to 0·5 per cent. of the combined acids as a rising bath. As the mixture is a weak one, it may be found convenient to leave the pelts in the rising bath over-night and draw the pelts for transferring to the salt bath next day. This bath should contain salt to saturation and sufficient salt lying on the bottom of the pit to allow for the take up by the pelts. The pelts may be continuously paddled in this mixture for an hour and then left to fill quietly prior to taking them out and sorting into grades, which is done by straightening the classed skins out of salt brine on to tables. When a pile has been made sufficiently high, count into bundles of one dozen each, fold from the neck to butt, and store away in a cool room until required.

This method calls for no wet work on the part of the fellmonger, and leaves the pelts in a properly cured condition, which is closely comparable with the condition of fresh pelts, to which they may be restored by the buyer washing all the pickle out with fresh clean water. When all trace of pickle has been removed the limeyard operations and the succeeding wet-work processes may be carried out.

The fellmonger gains the glue pieces which will compensate him for his expense and labour. The tanner will receive the pelts in a sound condition with no interference with the pelt so far as it applies to the application of the subsequent processes. Such pelts could be transported either in bags or casks, which would always be returned as empties. The adoption of some such changes in the processes mentioned, would be a distinct advance upon the prevailing methods and at once raise the status of the trade hygienically.

CHAPTER IX

SOME OLD AND NEW SUGGESTIONS FOR TREATMENT OF SHEEP-PELTS FROM THE FELLMONGERY TO THE TANNERY.

> "The rain falls; the springs are fed; the streams are filled and flow to the sea; the mist rises from the deep, and the clouds are formed, which break on the mountain side. The plant captures air, and salts, and, with the sun's aid, builds them up by vital alchemy into the bread of life, incorporating this into itself. The animal eats the plant; and new incarnation begins. All flesh is grass. The animal becomes part of another animal, and the re-incarnation continues."—HERACLITUS.

Introductory.—The writing of this chapter has entailed a considerable amount of thought, not entirely unattended with some amount of misgiving and anxiety in regard to a possible and unintentional misunderstanding of some parts of the text. This must be attributed to a common difficulty experienced by all writers in adequately describing with sufficient minutiæ of detail any complex or even simple process which is not based upon weights and measures, and which, while being reasonably scientific, relies largely upon the sound judgment and common sense of the operator. Nevertheless, every care has been exercised in making the description of the processes as clear and lucid as possible, and it is to be hoped where obscurity exists some light may be thrown thereon by reference to the historical notes.

The reader who expects to see in this chapter a recapitulation of the everyday processes carried out in the wet-work departments of any ordinary tannery will be disappointed, as they are specially left out, and should he desire any information thereon he is referred to the recent publications on the subject by Wood and others.[1]

The intention of this chapter is to give to the world the outcome of my life's work in connection with the improvement of processes connected with the several stages of raw pelt treatment. In the main my desire has been to evolve rational and hygienic methods or processes antecedent to the tannery and comprised in that comprehensive term "wet-work." Such processes as described are familiar to many, but will doubtless appear to others as almost revolutionary and dangerous. The methods outlined were devised by me many years ago, and have been, under my directions, applied to many millions of skins, and have also been utilised with every success by friends to whom the processes were disclosed. It is hoped, therefore, that the reader will approach the suggestions with an open mind, and a determination to make them succeed under his hand and thus reduce the charge levelled against the leather industry of being an *offensive trade*. The reader may experience some preliminary difficulties through lack of fully appreciating every point, but, with a little persistence and local adaptation or modification, success will be achieved.

So far as it is possible, the use of scientific terms has been avoided and only those which are in common use among the wet-workers introduced. This must not be taken as a slight upon the reader's ability to appreciate such terms, but arises from a desire on part of the author to get home with the average workman who has to carry out the processes and who, after all, is the man who will, either intelligently or not, carry out the work in its detail.

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[1] The student who desires to study the *rôle* of bacteria in the wet-work should read, "The Puering, Bating, and Drenching of Skins," by Mr. J. T. Wood.

Bacteria as Enemies to Sound Leather.—In the preceding chapter I have touched upon the importance of treating all the various peptonising groups of bacteria which invariably accompany raw pelt matter as enemies in the production of sound leather. As will be seen by reference to the Appendix, the species are many, each having its own special and peculiar function to perform. To them all, the skin (gelatine) is so much food and a suitable medium wherein they can support and reproduce their species until such times as they have either exhausted their food supply or they have become so numerous as through overcrowding to bring about their own extermination by the accumulation of their excretions, or poisons. In every stage of the processes which precede that of tanning "the silver cord of the bundle of life is loosed, and earth returns to earth. The microbes of decay break down the dead, and there is a return to air and water and salts. All things flow."[1]

The importance of recognising their presence at every stage of the raw pelt condition from the fellmongery to the tannery requires to be fixed securely in the reader's mind, as they are the cause of more mischief in the production of inferior grains than any other error in working. The reader must often have noticed when carrying out the dyeing and finishing operations the presence of certain patches of weak grain on the skins, and been puzzled in regard to their causes. There may be a weak grain which cannot be attributed to wind, air or water blast, but displays a peculiar, irregular, map-like disturbance of the glassy surface, varying in depth in different places in the same patch, sometimes showing a clear disturbance which has a network formation, or resembling the clouding which comes over a looking-glass when gently breathed upon. Such defects may occur or be produced anywhere between the wool-pulling shop and the tannery, and it is not so simple to locate the exact spot as it would at first appear; but the following explanation, taking a typical case, will doubtless enable the reader to understand the cause and apply the remedy.

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[1] "Introduction to Science," by Professor J. Arthur Thomson.

Bacteria are most dangerous and destructive when left in perfect peace. We will take as an example a fellmonger's gathering limes, although the same principle may equally apply to the soaks, the old limes in the tannery, the puer tubs, the drenches, etc. The pelts after being dewooled are usually transferred without any preliminary treatment to an old (and so-called weak ?) gathering lime, into which they are thrown and sink down into the liquid, where they remain until such times as the pelt-sorter comes along and buys them. The amount of liquid displaced by the pelt is very little less in weight than the pelt itself, hence the pelts, being almost the same weight as the liquid, do not sink down like lumps of earth to the bottom of the pit but gently float, and in floating form pockets containing liquid plus the organisms of putrefaction adhering to the skin. The liquid is most admirably adapted to their wants, and the gelatine gives them the necessary food. Lying at peace within the pockets, the countless millions of putrefactive germs operate on the exposed surface of the skin ; if it be the grain, then the delicate glassy surface suffers by their depredations, thus producing the cloudiness or blasted appearance of the grain ; if the exposed surface be the flesh, then the dåmage is not so apparent unless the bacterial action has been prolonged. Such delicate grain disturbance is not always to be noticed in the pelt stage ; it becomes more defined when the skin is tanned and dried or coloured, owing to the absorption of the colouring material in different ratio. This defect will be touched upon later on, but the reader should wake up to the subtleness of the unseen enemies within the gate.

Historical.—It is impossible to say when the denuded pelt was first used in the form of leather in the economy of man ; that some kind of leather was made by Neolithic man is demonstrated by the suggestions of foot coverings found on the skeletons in the neolithic graves in Denmark. It is probable that the very earliest uses to which a sheepskin was put by man was a covering for the body, employing the wool inside or out according to the state of the weather. Later, as the intelligence of man developed, he would observe that, under given conditions, the wool and the pelt parted company by the process of sweating or staling, and he would further notice that heat and moisture played a part in the process, which observation he would apply empirically to future lots. He would doubtless note the fact that the greasy sheep pelts were softer than those containing less fat, and he would apply fat to the skins and so inaugurate "oil dressing." As skins were often fatted on the ground, it is surmisable that such ground, or soil, may have been in certain instances alkaline, saline, or aluminous, qualities which would be absorbed by the pelt while lying thereon, and so the early tawing would be brought about. Sheepskins were used in the raw state for tent covers; inside, during cold weather, the peat or wood fire would smoulder and the smoke fumes rise creeping up the sides of the tent with the flesh side of the sheepskins exposed to the smoke until it finally found its outlet in the aperture provided around the apex of the tent. Thus a smoke tannage, such as is to-day in vogue among many tribes, would be introduced. Later, the astringent properties of barks, seeds, etc., would naturally be tried by the earlier seeker after "tips," and tanned leather would result.

In dewooling or dehairing, according to Philippo,[1] the dung of animals was early used to smear over the flesh-side of skins and hides to hasten the depilation. The use of lime for depilating brings us down to quite modern times and, like many other methods connected with the leather industry, had its birth in the East. The earliest records point to Asia Minor, where the ancient Morocco leather, as described by Philippo, was dehaired by painting the flesh side with milk of lime. Previous to employing lime, ancient experimenters appear to have tried various methods of dehairing, employing various ferments of barley, wheaten bran, figs, honey, etc. In the eighteenth century the use of bran ferments was well established and caused considerable concern to the Government of France, who in 1740 prohibited the use thereof, either by tanners, starch makers, or brewers, on account of the great scarcity; it was stated that the amount of bran required for one hide was sufficient to support a man with food for two months.

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[1] "The Art of Tanning and Currying Leather. With an account of all the different processes made use of in Europe and Asia for Dyeing Leather Red and Yellow. Collected and published at the expense of the Dublin Society. To which are added Mr. Philippo's Method of Dyeing the Turkey Leather as approved of by the Society for the Encouragement of Arts, etc., and for which he had a reward of one hundred pounds, and their Gold Medal, for the Secret. Also the Method of Tanning invented by the late David Macbride, M.D., London. Re-printed for J. Nourse, in the Strand, Bookseller to His Majesty. MDCCLXXX."

Lime would appear to have been employed in the European leather industry first in the south-eastern corner of Europe about the time of the Greek civilisation and to have travelled slowly across Europe as civilisation and interchange of thought progressed until it became in common use about the fifteenth or sixteenth century. Its early employment on hides was interestingly curious and somewhat inexplicable. No doubt the lime was badly burnt, nevertheless strong; all the lime liquors were "new limes" and the hides were left in for periods varying from a few months to as much as two years. This method is still in vogue in certain European tanneries. All the available evidence goes to show that after the sheepskins had been dewooled they were never left in a lime liquor for more than ten to fifteen days.

The employment of bran from barley or wheat, also other fermentative products such as honey, figs, etc., as bating agents would appear to have been introduced at a very much earlier period than that of lime, and the uses to which ferments were put were numerous and varied. This process, or processes, also originated in the far East where nature displays a strong desire to ferment many of her by-products under suitable conditions. The action of ferments in the production of the various natives' drinks must have been known to very early man, and the step from one to the other is not too difficult to realise. It is nevertheless interesting to know that some of those ancient methods prevail even at the present day. Although the science of chemistry played no part in the discovery of such processes, yet the power of observation and deduction exerted no mean influence, and the result attained was secured after much patience and trouble, with loss of valuable time and, possibly, value. With our increased knowledge due to patient research we are able to explain the parts played by the various organisms and thus control them and make them do our bidding, and in some cases to perform the same operation with greater certainty of action and without the attendant risk.

Dung from dogs for bating or puering is likewise of Eastern origin, but of comparative recent date, and was apparently used on goat skins in Asia Minor during the eighteenth century and possibly a hundred years before, but not earlier. Philippo says: "In July, 1735, the plague raging greatly in the Island of Cyprus, a person represented to the governor of Nicosia, that the dogs contributed greatly towards that disorder, upon which he ordered all the dogs to be killed. The curriers and merchants, hearing of this order, went in a body to the governor, represented that the commerce of morocco was of great importance to the city, and that it would be ruined if the dogs were destroyed, as their dung was absolutely necessary to the preparation of morocco. This remonstrance appeared of such consequence that the edict was revoked at all hazards."

Philippo describes at length the earlier or previous method of bating which continued in common use in certain districts for the preparation of morocco: "The hair skins were painted with a solution of lime and hung over poles after folding belly to belly, until the hair became loosened, then it was removed over a beam with a knife, and the pelts entered into a lime liquor, in which they were left for three weeks, then fleshed, and well washed before drenching. The water was well squeezed out of the skins, and next they were placed in a bran drench made up of about a pound of bran to the gallon of water. After three days' working in the drench, they were taken out and well worked over a beam with a scudding knife, then again returned to the drench for two days longer, when as they were taken out each skin was well rubbed with the hand and the liquor squeezed from the skin, then the bran cleaned off from each side, finally washed through ten waters and again freed from all water. A bath was then made up of one pound of honey dissolved in three pints of water (luke warm), to which two handfuls of bran was next added, and thoroughly mixed, this mixture being sufficient for four skins, which were well worked in it until all had been absorbed. Afterwards fold up each skin separately into a round form, with the flesh side inwards, and lay them in an earthenware pan, or other proper vessel; if in the summer, by the side of each other, if in winter, on top of each other. Place the vessel in a sloping position, in that such part of the fluid may spontaneously drain from the skins. An acid fermentation will then rise in the liquor, and the skins will swell considerably. In this state they must continue for seven or eight days, but the moisture that drains from them must be poured off, once or twice a day, as occasion may require." After this a further preparation with salt is necessary; which must be performed in the following manner: "After the skins have been fermented in the honey and bran, as above mentioned, let them be taken out of that mixture on the eighth or ninth day, and well rubbed with dry common sea salt, in the proportion of about half a pound to each skin; the salt must be well rubbed and worked with them. This will make them contract again, and part with a further considerable quantity of moisture; which must be squeezed out by drawing each skin separately through the hands." This salting was repeated several times until the skins were thoroughly pickled. In this condition, after being freed time and time again from excess water, the skins were ready for dyeing, which always preceded the tanning operation.

This is possibly the earliest reference to the art of pickling, and is not without a bearing upon the success which has attended modern methods.

The introduction of dog excrement for puering skins in England is apparently of quite recent origin, possibly early nineteenth century. The employment of excrement from hens and pigeons is essentially British and only applied to hides.

The oldest of all modes of bating would appear to be that known as the "stream process," which consisted in immersing the pelts in a flowing stream of soft water and continuously working them out over the beam; this was succeeded by the fermentative process. The early use of the ferments for the purpose of removing the hair would attract the tanner's attention to the flaccid condition of the pelts after the operation, and thus the application of bran drenches as a puering agent to remove the lime would follow in due course.

Until within the last ten years the use of bran drench alone for bating was in vogue in some yards devoted to sheepskin tanning, and was carried out as follows: the pelts, after liming, were fleshed and all offal trimmed off; next, without any preliminary washing, they were introduced into a bran drench. The drenching was invariably carried through in circular stone-built pits of small dimensions and situated in a low building to which the only light admitted found its way through the door when opened; such pits would hardly ever be connected with any sewage system; the old liquor being removed by hand pumps. In the pit to be used sufficient water was run to fill about half the pit; the water being drawn cold from the local stream which usually accompanied all tanneries of ancient date; on top of the water a handful of bran would be thrown, then a pelt thrown spread out, then another handful of bran thrown on the top of the pelt, next another pelt thrown spread out on top of the bran layer, and so on until the pit was full, when the whole mass would be pushed down into the liquid so as to cover the pelts with the drench solution. About one hundred pounds of bran would be used for five hundred pelts. If the operation was being carried out during the winter months, the pelts would first rise to the top of the drench in about three weeks, then they would be pushed down and in the course of a day or so they would again rise, and the rising became shorter in time with each successive rise, until they would cease to rise after some six weeks' lapse of time from the time the pelts were first introduced into the pit. If the drenching is performed in the summer months, the operation will be completed in about three weeks, according to the temperature and local conditions. When the pelts cease to rise, they are taken out and scudded over the beam, and it is interesting to observe the small amount of scud which can be worked out. This method of drenching, while being malodorous, produced excellent firm leather, yet mellow and very tough to tearing or breaking strain. Daily records of temperature which I kept over a period of two years, using a Sixes thermometer in two tanneries where the process was carried out, showed that the thermometric variations during any portion of the year, either in the atmosphere of the drench house or in the drench, rarely varied more than a few degrees Fahrenheit. The average winter temperature was about 40° F. and the summer about 53° F.

This process had a curious and useful advantage for the tanner; if his tanning capacity was full, then, after scudding, the skins could be spread out flat one on the other and stored away rolled up in convenient bundles, until such time as was convenient for tanning, and no deleterious results ensued. Sometimes the pelts would be salted prior to storage; but in all cases they were salted before tanning, and the first tan liquor was likewise salted, then, being exhausted, was run away, and all the succeeding tan liquors were fresh, being usually made from oak bark brewed by cold leaching, weak in tannin but strong in volatile acids.

If the skins were greasy, they were, after salting and prior to tanning, wrung in chain formation, by rolling two or three skins together, coiling the ends inwards to form loops, placing the first loop over a hook fastened tight in a post; then another lot of skins were looped and inserted in the first, and so on until a full length of chain had been formed; the final loop being hooked into a revolving hook in an opposite pillar. The revolving hook was extended through the post and attached to two long cross arms like the letter X. By means of the cross arms the chain was twisted until the fat began to flow, then the cross arms were anchored by suitable means and the operator proceeded to pour warm salt water over the chain to induce the fat to flow and drop into a receptacle underneath the whole length of chain. The chain would be tightened from time to time and the warm salt water applied until the worker was satisfied that all the grease had been wrung out. This method has in modern times been superseded by the hydraulic press and chemical means.

The Skin a Colloid.—For the benefit of the non-scientific readers, it is only fair to say that a colloid, as distinct from a crystalloid, merely represents that state of matter in which the chemical individual, instead of existing in molecules, is present in large aggregates of molecules. Thus such a body is liable to assume the gelatinous form, is in most cases non-filterable by ordinary means, has a very small effect in lowering the freezing point of water, and can exert very little osmotic pressure. It must, however, be thoroughly understood that we cannot strictly speak of a colloid, or of a crystalloid, but merely of matter in the colloidal or crystalloidal condition, as all substances have now been obtained in the colloidal condition, and there seems little reason to doubt that ultimately all substances will be obtained in the crystalline condition.

The above idea, although difficult for the average reader to grasp, is best conveyed by the statement that the colloidal condition can be represented by *gelatine, egg-albumen, gums, etc.*, while the crystalloidal condition is represented by *table salt, washing soda, etc.*

It is a remarkable fact that the common characteristic of all tanning materials is such a colloidal condition. Hence, as the skin matters are also in the colloid state, the problem of tanning reduces itself in the first instance into the mutual coprecipitation of two colloids of opposite electrical charge.

The skin is a mixture of colloidal individuals, composed of countless living cells containing protoplasm which is likewise colloidal, whether living or dead. The acceptance of this simple proposition is undoubtedly the keystone to successful leather production. It is true that the pelt appears to the tanner as a fibrous structural mass, and it will be as such we shall discuss the various points.

Sheep Pelt Physiology.[1]—This subject has never been fully treated by physiologists, nor does any literature exist on the matter. Such as may appear in the various text-books is in a large measure the outcome of investigations pursued in regard to the human skin, and it is feared that errors have been perpetuated by various writers who simply copy from one another. It is true that Kathreiner and Procter did valuable work which has been published in the latter's books, but that work mainly applies to hides rather than to sheepskins.[2]

Like all skins of the mammalia, the sheep pelt is constructed of different layers which are more marked and clearly defined in the sheepskin than in any other skin or hide used in the art of tanning.

The outer layer, the *epidermis*, is always removed during and by the act of depilation, consequently does not materially concern us, except to say that it is keratinous in character, and, if not removed, the grain after tanning will crack easily on bending. The next layer, familiarly called the *grain,* is composed of the shiny surface commonly termed the *hyaline* or *glassy layer*, which, if it exists at all as a separate layer, is of most minute thinness. Below is the *rete malphigi* in which what appears as the grain formation is the characteristic feature; this in turn lies immediatley on top of the *true skin,* which by comparison with the total pelt substance is thin. Below the *true skin* is the *fatty-layer* in which all the wool roots and wool follicles terminate. This layer in domestic sheep pelts is full of fat, and is the layer which the splitting knife traverses to split the grain from the flesh. Thus we see that the grain or skiver is composed of the *true skin* in the main, plus a certain amount of the *fatty layer.* Immediately following comes the *leather skin* which varies in thickness in different breeds of sheep pelts, and is the layer upon which the act of shaving is performed to level the skin, or, as in the case of a hide, the layer into which the tanner fills the tannin in order to obtain the requisite weight. Adhering to the *leather skin* is unequally distributed an extended mass of muscular tissue, the *panniculus carnosus* or red muscle. Its distribution varies slightly on different sheepskins according to the breed, but generally it covers the whole of the neck, chest, belly, sides, flanks, as well as the immediate rump or very end of the butt, but is non-existent on the back, starting from a point in the lower shoulder, where it divides in a V shape, ever widening until it approaches the rump, where it forms the base of a triangle. This muscle plays many parts, not the least being that of

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[1] In order not to anticipate a work on the histology of the skins which enter into the art of making leather, which it is hoped will be ready for publication this year, by Professor de Burgh Birch and the author, the section on skin physiology as given here is brief and must be accepted with a certain amount of reservation.

[2] See Procter's "Principles of Leather Manufacture." (Spons.)

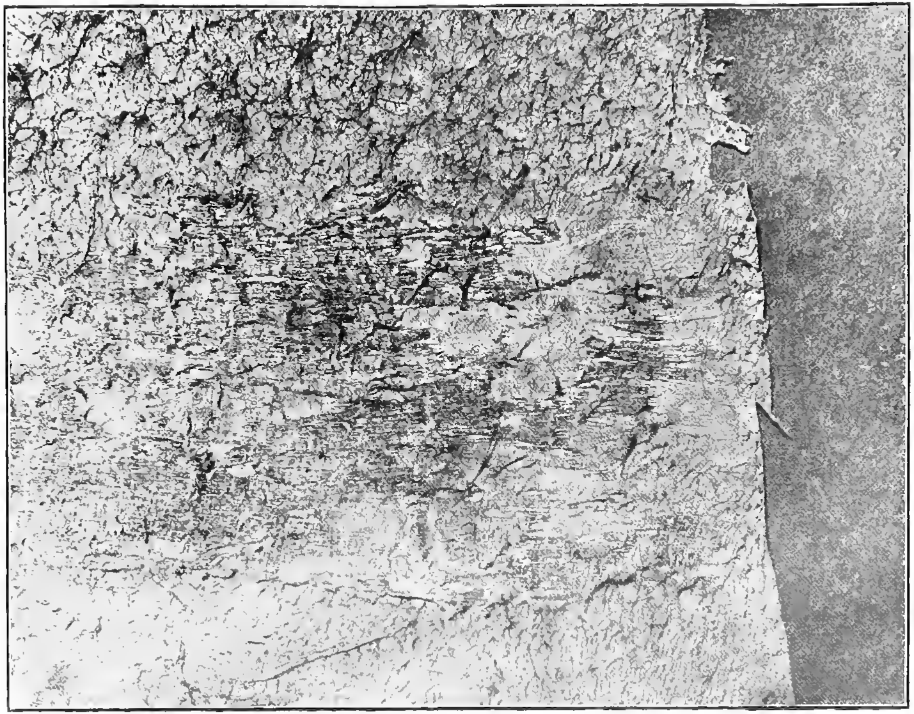

PLATE 36.

Photograph by the Author of the flesh side of a sheep-skin after tanning. The "Red Muscle," or *panniculus carnosus*, will be observed as dark-lined or broken patch in the centre —from right to left—and about two inches wide.

twitching the skin when bitten by insects and flies. With the increase of artificial feeding and quietude of the sheep's life there is a tendency for this muscle to undergo degeneration and atrophy in domestic sheep. This layer has adhering to it a mass of loose connective tissue, largely composed of fat, and some muscular fibres which, together with the *panniculus carnosus*, form that substance removed by the act of fleshing.

We have, therefore, to deal with three very distinct and more or less compound layers in the skin for tanning, the *grain or true skin*, the *fatty layer*, and the *leather skin* ; each is chemically different, and during life has different functions to perform, and in consequence it will be found—as is in fact already known to all observant sheepskin workers—that each layer requires different modifications of treatment during the various processes as they succeed each other. As regards character and thickness these layers do not always exist in precisely the same degree in all sheepskins ; hence the difficulties of successful sheep leather production are increased in due proportion as the successive layers may vary in different breeds ; therefore it is of supreme importance that all pelts should be carefully and diligently sorted into classes as to breed, growth, state of liming already carried out by the fellmonger, before proceeding with the liming operation in the tannery.

The *grain* or *true skin* is distinctly a close fibrous mass, containing a greater mass of elastin than is the case with any other layer ; this may be readily confirmed by taking a freshly split pelt, holding the *flesh* in one hand and the *grain* in the other, and permitting both to hang down, then quietly jerking both up and down, when it will at once be seen that, while the *flesh* has scarcely any elasticity or spring, the *grain* has a considerable amount. Each layer, while being fibrous, differs materially in character both chemically and physically. For example, take the case of heat; the *grain* may in the limed condition be submitted to a much higher liquid temperature than that of the flesh, a feature well known to all puermen.

The *grain*, being the outside skin layer of all animals, must of necessity be more extensive in area than that of the *flesh* or *leather skin*, which occupies an inner circle. It has to accommodate itself to nature's necessities, which demand expansion and contraction due to atmospheric changes, and the increased growth of wool or hair at varying seasons of the year. This increase in *grain* area is considerable, being most marked in the merino sheep, which, as is well known, is frequently heavily ribbed; that is, the *grain* rolls up in rib formation, sometimes as high as half an inch, and extends throughout the whole of the skin surface. This rib does not affect the area of the *leather skin* or *flesh*, which remains the same (in area) as the size of the carcase from which the skin was taken; therefore the *grain* after splitting always increases in area by several inches all round, according to the size, character and breed of the sheep, not necessarily or materially thereby reducing the substance, but as a result of its having been released from its bonds (the fibres of the *fatty layer*) which unite it to the *leather skin*.

The *fatty layer* is composed of coarse connective tissues, between which lie the mass of fat lobules (see Plates 11, 12), also wool roots with their shafts and wool follicles, with numerous sweat glands traversing the whole layer and finding a termination in the grain surface, but never entering the wool follicle or root. This *fatty layer* exists in the skins of all animals, but in varying degrees of thickness ; in a buffalo hide it is so indistinct as to be difficult of detection ; it is slightly more marked in a well-fed ox hide; the goat shows it in varying degrees of thickness ; the sheep shows it most markedly ; in a hog skin it does not appear, because it is represented by the heavy layer of fat which is seen in the morning's breakfast bacon ; it is also absent in sealskins. In all mountain breeds of sheep, and the hairy sheep of the East, it is seen as a more or less thin and solid layer, but as cross-breeding and artificial feeding increase, so is this layer increased, owing, in a large measure, to the increased growth of the *fatty layer* fibre and fat cells, and partly at the expense of both the *true skin* and *leather skin.* A grain off an artificially fed sheep always exhibits a coarser and looser fibre structure, with a general decrease in the number of normal fibres and an abnormal increase in fatty deposit, which is easily removed during the scudding operation, hence a thinner skiver results. Where such skins are destined for basil tanning the difficulty of obtaining a firm, solid skin after tanning is comparatively increased.

The *leather skin* is the only other layer of a sheepskin from which leather is made, *i.e.* wash leather, chamois, glove leather, etc. As compared with the *true skin* it is an almost non-elastic structure composed of closely interwoven fibres, running in and out, intertwining in every direction, interlocking, always directed more or less in an outward direction from the flesh until they converge on the *fatty layer*, at which point they assume a closer and finer character, appearing as though matted together. These fibres are of several kinds, varying from the muscular to the white fibres, the latter being predominant. Like all other parts of the skin, the fibres are the result of a definite cell growth, the arresting of which growth, through disease or other causes, produces thin skins; and often, as in the case of *Fluke* or *Liver-rot*, a diminution in area; on the other hand, if they are abundantly supplied with nutritious food through the animal system, they will increase the total substance of the pelt. Interspersed throughout the fibres may be seen small aggregations of fat lobules of a lesser kind than those of the *fatty layer*. The *leather skin* fat lobules are a necessary concomitant to the strength of the skin, being very evenly distributed, and in practice should not, if possible, be disturbed during any process of manufacture; where they are displaced, as is too frequently done, where hydraulic pressing is in vogue, to express the skin grease, such fat should be subsequently replaced mechanically and if possible before, or immediately after, tanning. This layer forms usually the most substantial part of all skins except the hog or seal skin, in both of which it is non-existent. It differs both chemically and physically from both the other layers; lower liquid temperatures have to be employed, yet it will stand rougher treatment and is far easier to work.

In consequence of the differences, both chemical and physical, of the three layers, particularly the *true skin* and *leather skin*, the character of the colloids (the layers) should bear a relation to the cause and effect between the colloidal equilibrium of these substances and the chemical equilibrium of their constituent parts. The maintenance of these equilibria, when once ascertained, implies the successful production of strong sound leather.

The Raw Woolskin.—Although it has been truly said that the body of a healthy animal contains no detrimental bacteria, nevertheless the same remark cannot be truly said of the exterior surfaces of the skin. Scattered over the surface of all skins are countless and numerous colonies of bacteria awaiting the opportunity for attack when the suitable moment arrives. These organisms find during life a quiet resting place in and adjacent to the openings or apertures of all kinds in the skin surface, and are sustained by the exuded juices, thus enabling them to reproduce their species. After flaying, and as the skin cools, the opposition of the opposing faculties, which are always present in the living body, ceases to combat the energies of the exterior organisms due to the death of those protecting germs, and, unless the skin is sterilised or treated with some antiseptic material, such as salt, the putrefactive or exterior organisms will commence their triumphal entry into the skin, which they will make down the sweat duct and hair follicles. It must obviously be easier to prevent their depredations, before they have obtained a hold, by treating the skin with some suitable antiseptic cure, than to delay matters until they have completed their grip.

In order to obtain the necessary lodgment, it is necessary that a certain amount of moisture should be present, which amount is the total moisture of the freshly flayed skin. If that total sum of moisture is decreased, then in proportion to such decrease so will their activities diminish, and as the dehydration is pursued a point will be reached when their energies will be totally arrested, but not necessarily sterilised; that is, they will have been but temporarily paralysed, and will again resume operations when the normal conditions as to moisture are restored. In fact, it is an accepted axiom that the history of all life is bound up with that of liquid water; *life is an aquatic phenomenon.*

In general practice, the salting of hides or skins seldom withdraws sufficient moisture in order totally to arrest the activities of all the putrefactive organisms. There are classes of such germs which are capable of sustained life and action and of decomposing pelt matter in a minimum quantity of humidity, such as is found in well-salted stock, although such incipient putrefaction proceeds very slowly and with considerable difficulty, nevertheless it does so with persistency. In order to meet this phase of the problem, a salt containing some sterilising agent should be employed. Woolskins usually contain free liquid, especially when they have been carelessly exposed to rain or permitted to gather up moisture in the slaughter house. Such skins, when placed in a pile or heap for storage or transit, develop heat, especially during the warm months or in muggy weather, and in all such cases—unless the skins have been properly cured—putrefaction proceeds rapidly.

The readiest method of withdrawing moisture from a woolskin is to spread finely powdered salt over the entire flesh after the skin has thoroughly cooled, and to continue the salting until the dehydration is satisfactory.

Within a wide range temperature affects these organisms; heat as a rule aids while cold retards them in their work, but freezing does not destroy them. Under almost all alkaline conditions they will thrive, and have been known to adapt themselves to tannery life. They are under all conditions the worst enemies the leather manufacturer has to combat.

Limeyard Work.—It is a hackneyed phrase to say that sound leather is made in the limeyard. Like most axioms it contains a modicum of truth, though what is left unsaid is apt to mislead the learner. To be accurate, the axiom must be comprehensive and thus rendered; sound leather is made or marred according to the diligence, care, foresight, acumen, and common sense displayed by individuals in the performance of the various processes as they succeed each other from the first act of flaying to the moment of introducing the skins into the first tan liquor. The three prime factors in the production of sound leather are: (*a*) sound flaying, thus furnishing an uncut flesh; (*b*) a rational cure of the flayed pelt to secure the maximum of conservation; (*c*) intelligent fellmongering, which implies a reasonable appreciation of care of that valuable product *the grain*, which when injured causes serious depreciation in skin value. It will be seen that these three vital factors all precede that of liming, the failure to secure the proper performance of any one of which at once negatives all value in liming. *Liming will never correct the preceding pelt damages.*

The reactions which are supposed to proceed during the liming operation have been described by many investigators, each one treating the subject from his own special standpoint, be it the hide from the ox, buffalo, hog, goat, or sheepskin, but as yet no one has adequately described why it is we lime a skin. Recently Cav. Uff. Ettore Andreis,[1] delivering an interesting address on the "Process of Liming," which may be said to be the latest publication on this question, sums up the objects of liming as—"to attain strength, pliability, and mellowness of leather;" and he adds with justice, "above all, strength is required."

It is generally agreed that the matured healthy skin as it leaves the animal's back possesses the highest qualities in regard to strength of fibres. This must be due to certain chemical and physical combinations at present neither understood nor fully appreciated; hence it is of supreme importance, if strength is to be secured, that the various chemical, physical, and colloidal equilibria in the living skin shall be maintained in the pelt after it has emerged from the beamhouse and is ready for tanning. If this statement is admitted, it will be agreed that, during the successive operations of wet work, these equilibria (as they exist in the healthy skin) are constantly being undermined.

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[1] "The Process of Liming," a lecture by Cav. Uff. Ettore Andreis to the Students attending The Royal Tannery School. Turin. Published by the proprietors of the *Leather Trades Review,* 24, Mark Lane, London, E.C.

Most valuable research remains to be done to determine with exactitude those chemical and physical properties which go to constitute what is termed strength in a hide or skin. Personally, I have attributed it to the presence of calcium in the main, with possibly phosphorus, chlorine, and sulphur compounds, the chemical or physical combinations of which are being constantly changed during the wet work, and which form a mineral skeleton base throughout the skin. Unfortunately our knowledge to-day is very incomplete upon the subject, and prevents us from giving a full and truthful description of precisely what it is that happens in or during the liming process. We must therefore rest content with theory and trust to our experience to carry the processes out empirically.

Provided the chemical and physical premises are admitted, then we may assume that a primary function of liming would appear to be to *carry forward within the skin sufficient lime salts to form a base for the wet-work operations to be successfully carried out without robbing the skin of its natural lime salts in combination.*

But apart from this, liming performs other important functions. Being soluble only to a limited extent, it is a safe alkali to place in the hands of non-scientific men. Like all alkalis and acids it has the power to dissolve a certain amount of the interfibrillary tissue, the dissolution of which may or may not be due to the various bacteria present, thus giving the loosening effect desired for given classes of leather, and in this manner to prepare the skin to receive a greater amount of tannin or weight. The swelling effect is necessary in order to prepare the pelts for splitting and to break the fibre bundles from their bonds.

It is claimed that liming will enable the wet work to remove the skin fat, which is very doubtful, as lime saponifies the skin grease into an insoluble lime soap which is difficult of removal subsequently in any ordinary wet-work operation. Cases may occur where the swelling when carried to extremes will in turn swell the delicate sheaths of the fat lobules until they burst and release their contents to be worked out later over the beam, but it is very problematical and too risky a process on which to rely absolutely.

An underlimed pelt, or one which has never seen lime, always tans out to a flat and thin, tight skin; on the other hand, provided the liming is too prolonged and excessive, what is termed over liming occurs, with consequent destruction of the tissues, a fault which no subsequent process can ever successfully remedy. This over-liming is akin to that disease known as "calcification or ossification," in the human being.

Liming is generally credited with the power of removing the short undergrowth of hair, commonly called "short hairs," so often seen on almost every class of skin depilated with milk of lime. It is safe to say that every limeyard foreman knows that liming has failed in this respect, and sodium sulphide, with combinations, has been added to the lime liquors to assist the operation, but only with partial success.

In order fully to appreciate and understand the difficulties surrounding the problem of removal of fine hairs, we must turn to microscopic investigation. If a micro section be cut from a sheepskin in the wool, and if, after removing as much of the protruding wool as possible with scissors, the section be laid out flat on a glass slide (uncovered) and examined with a suitable low-power objective, it will be observed, on examination and on comparison with sections similarly cut from other animal skins such as those of goats or oxen, that the wool roots are not placed equi-distant from each other but are grouped in bunches; further, that although the wool shafts penetrate the outer surface of the skin at first in a line at right angles to the skin, they become inclined below the grain and terminate in a bend at the root base or papilla. If the wool belongs to a very curly class such as merino wool, then this final hook formation assumes a shape which may be compared to the letter J, with a big knob at the termination of the curl. This phenomenon is never seen in any hair or fur skins. The fine hairs are invariably those hairs which are taking the place of wool which has fallen, or is falling, out, or may have been pulled out by thorns, etc., during the life of the sheep; they are specially noticeable on scabby patches of skin. From the centre of the old wool shaft, as it falls away, a small and fine shaft of new wool appears, having its root embedded in the position vacated by the old wool shaft; this root is almost as large as that of the expelled wool and rapidly grows and assumes a size equal to that of the old wool root. Meanwhile the expelled wool having left the follicle, this tube closes up around the young fine wool shaft, thus accommodating itself to the new conditions. At this stage the root is more mature, especially as to bulk, than the adhering wool shaft, which is enclosed in a follicle of narrower diameter which still possesses the same power of muscular contraction. It is at this stage that the fine hairs are met with. The position is a curiously interesting one. We have a fine hair encased in a contracted wool follicle and just protruding above the external surface of the skin, delicate, soft, tender, and fine, with a large root buried deep in the *fatty layer*, often curled in such a manner as to form a hook. The reader may well imagine the difficulty of removing a fine hair through so narrow an aperture, root and all. It is comparable to the Eastern saying of passing a camel through the eye of a needle. When the fine hairs are very young they are not so readily dissolved with sodium sulphide as is the case later when their keratinous character has been well formed. The fine hairs are more readily removed during the process of wool pulling than subsequently; from observations I have made on sheep pelts, it would appear that when fine hairy pelts go into a fresh lime liquor, the root, previously soft, becomes hardened, and hence more difficult of removal.

The Character of Lime.—Limeyard workers differentiate between, (*a*) hard lime or sharp lime which they frequently refer to a "fiery lime," and (*b*) soft or mellow lime. These differences convey to the average non-scientific mind certain properties exerted by various limes. It is a matter of considerable difficulty to assign any scientific reason for these differences as the analytical results show that both varieties, when well burnt, have similar compositions. Whether these differences can be ascribed to the different chemical constitutions of the original limestones or to a hitherto undetected and varying physical structure, we have no evidence to guide us.

The following practical observations may be of interest to the reader. The oldest limestone is furnished by the limestone measures of the Silurian system and by the fossiliferous limestones of the Devonian system. These two produce what are termed the sharp or fiery limes. The rock is particularly hard, and is largely used in buildings and such places where it is necessary to provide a stone which is not easily affected by the elements; it is also used for road macadam, but is not sought after for plasterers' work because it does not completely slake during the first slaking process but goes on slaking for weeks after being made into putty, yet it makes an excellent mortar and cement. In the leather trade this lime is credited with producing a firmer pelt and generally a harder leather; during the process of deliming it offers greater resistance to the reagents employed, thus the condition of flaccidness is retarded. Such lime should be employed in the production of sole leather.

The soft or mellow limes are the product of a very much younger limestone formation, viz. the Mountain limestone, the Chalk or Cretaceous limestones, which all plump the pelt but do so with a mellower and kinder feel, which continues throughout the wet work with the result that the beamhouse work is much simplified and the resultant leather carries with it a softer and kinder touch. This group of limes are essentially dressing leather limes.

The Silurian and Devonian limestones are common to Wales and Scotland, while the Mountain limestones are typified by the Derbyshire (Buxton) limestones, and the Chalk or Cretaceous by the measures of the South of England. It may not be out of place to observe that there was a lapse of many millions of years between the formation of each of these series of limestone measures, and it probably follows that the animal and vegetable life which, by accumulation, built up these measures during those countless millions of years would doubtless be chemically and physically different from each other, although, of course, originally derived in remote ages from a common stock, but possibly the increased pressure and heat may have played an as yet undetected part in their character which calls forth the descriptions of sharp or fiery limes and soft or mellow limes.

In India and South Africa the lime is prepared from sea-shells, and is credited with great mellowness, the native tanners claiming that it is a prime factor in the production of their soft leathers.

It is unfortunate that our lack of scientific knowledge of such an elementary substance in tannery use as lime is so barren that we are unable to give to-day a complete and satisfactory explanation of these curious and interesting empirical results.

The Slaking of Lime.—All lime should be purchased as fresh as possible from the kiln and on receipt promptly slaked in a suitable pit built in the ground. After slaking water should be added, and the whole mass worked through and through with a lime rake in order to permit of any stone present settling to the bottom, and after working the whole should be allowed to stand quiescent until set into a putty.

Many dressers of fine leathers, like glove leathers, add red arsenic (Realgar, Rhusma) to the putty. This can only be successfully accomplished by adding the powdered realgar quickly while the lime is slaking fiercely, intense heat being requisite to completely break up the realgar; after slaking run in the additional water and rake as previously instructed. When finally left to set the whole mass should have a blue-green colour throughout. Experience has shown that such limes, commonly called "poisonous limes," exert a peculiar and as yet unexplained protective effect upon the glassy surface of the pelts, producing stronger and brighter grains. The calcium hydrate produced has considerable destructive effect upon any fine hairs present.

To suggest the correct method of liming sheep pelt is not so easy of accomplishment as would at first appear, so much depending upon what final result the tanner desires to attain, but, speaking broadly, the following lines, with suitable modifications to suit individual cases, may be accepted: Assuming that the fellmonger has *not* washed the effects of the depilating material from the pelts before placing them in the gathering line in order to free them from all putrefactive bacteria, then such washing should be at once performed by the tanner on receipt of the pelts at the tannery and before putting them into any lime liquor. After washing it has been by some considered advisable to trim off all unnecessary offal; this is usually performed after liming, but it is not without advantage to consider whether the liming operation would be better carried out by the removal of all such offal, in order to avoid liming any unnecessary pelt matter and for the economy of lime pit space. After trimming, the pelts should be straightened upon a flat barrow and carefully inspected by an expert classer, and the pelts graded in regard to conditions of lime content, age of animal, general firmness, and such other qualities as may suggest themselves to the expert mind, with the view of securing during the liming process a regular lime treatment for all pelts according to their condition, and so helping to even up the final result both for the successful carrying out of the ensuing wet work and the final result in leather. It is too frequently forgotten that sheep pelts from local fellmongers have already been collecting in a gathering lime, which collection may have been slow or rapid. In either case some pelts will have received a longer liming than others, thus, at the very outset, the pelts have not all had equal treatment; further, such pelts will have already had a preliminary treatment in weak lime, thus the question as to the character of the first lime into which such assorted pelts should be placed will naturally arise. Where pelts have been advanced in lime action by the fellmonger, then such pelts obviously should not go into the same lime as pelts which have only just been depilated and probably have only been one day in the gathering lime.

The decision as to the character of lime to be given must rest with the limeyard foreman, who bases his judgment upon the salient features present as to lime, age, etc. In general practice it is usual always to place pelts as received in an old lime, *i.e.* a lime which is, in the opinion of the foreman, partially exhausted, and then to move them on after a day or so into fresher limes, until they are finished off in a new or fresh lime liquor. The whole operation must be governed as to time and advancement in lime strength, etc., by the previous condition of the pelts and the final destination of the goods, the period of immersion varying from a few hours to sixteen days.

In placing pelts in an old lime liquor, there is considerable danger arising from the putrefactive bacteria attacking the delicate grains, especially where the pelts have gathered into pockets, or the grain disturbance has already been commenced in the fellmonger's gathering limes, or where the pelts are left undisturbed for more than a few hours, especially during the warmer months of the year. The remedy lies in the avoidance of old limes and more frequent agitation of the pelts in the usual lime pits.

The newer the lime the more antiseptic are its qualities, but it must not be forgotten that putrefactive bacteria thrive in lime liquor under favourable conditions, and it has been shown by Wood and the author that with old limes the loss of valuable pelt substance is extremely serious, a condition strongly favoured by the introduction of artificial feeding. This phase of liming calls for close attention and observation on the part of all limeyard workers.

During the period of time the pelts are in the limeyard experience has shown that it is advisable to draw the pelts out of the pit daily, or every other day, and cess them up on the adjacent hearth or bank. This is conveniently accomplished with long tongs having iron knobs about the size of walnuts at the ends of the two tweezers. These should be covered with coarse jute or hemp cloth such as may be procured from rice bags ; tie double pieces round each knob to prevent nipping the grains of the pelts in case of a slip ; as each bunch of pelts is gripped and raised to the surface move the lot about in the liquor to wash them before placing them on the bank. The first haul of pelts should be spread out flat and grainside uppermost, to cover the area upon which the pelts will eventually lie in pile. When the whole pit has been banked, they should be covered over with pelts grainside in to protect the valuable grains from the evil effects of air, etc. In a properly arranged lime house all draughts or serious movements of air will be avoided, and such protection afforded as will prevent injury from the sun and elements.

Before placing the pelts back in the pit or changing them into a new pit, the pit should be well plunged with a wooden plunger, then the pelts should be thrown in, rapidly spread out with men at the pit sides to push them down, and distribute them equally over the pit area in order to secure uniformity of liming.

Many tanners avoid hauling the pelts by substituting paddles mounted on the pit. Where such is the vogue, they should be employed with the greatest care and judgment merely to turn the pelts over and to aid in hastening the process, *i.e.* the paddle should only be used to raise the pelts and alter the surface presented to the liquor and to rouse up the settled lime particles and bring them into solution wherever required. Paddling increases the action of lime to swell the grain surface, producing an unequal swelling effect, causing nodules of varying size to form on the grain with deep circumferential depressions; if the lime liquor is gritty the flesh side will fill with grits, and, as the skins are made to pass and repass each other by the paddle action, the nodules of the grain rub against the gritty flesh and thus grind off the fine glassy surface from the apex of the nodules, thus producing what have been appropriately termed leopard spots in the finished leather on the grainside. This same action may be produced where strong tanning liquors are employed at the onset when tanning in paddles.

The control tests for limeyard work have already been described on p. 280, which, while rough and ready, will be found an invaluable means of limeyard control in assisting the foreman to secure satisfactory results.

Chemical and Physical Phenomena.—All skin phenomena which we study objectively can be analysed by methods of chemistry and physics. In other words, we cannot get away from the laws of universal mechanics during the manufacture of leather. A study of these laws and the action and reaction and successive interaction has been hitherto neglected. For the purpose of this chapter I will speak of them as *physico-chemical* reactions as opposed to bacterial reaction. Before handling the physico-chemical problem it is of importance to enunciate a neglected fact, that every act performed during any process of leather production should be accomplished by persuasion, *i.e.* all force must be eliminated. The law of osmosis requires to be closely studied and assimilated by the worker, and he cannot do better than read up Chapter IX. in Prof. Procter's "Principles of Leather Manufacture," entitled "The physical chemistry of hide fibre," where the subject in question is treated with lucidity.

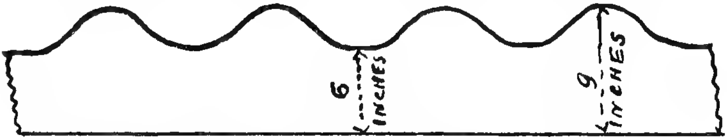
The successful issues of the ensuing processes of wet-work depend in a large measure upon the following factors: *Temperature.*—The success of almost all operations of a chemical or physical character depend upon the constant maintenance during the whole of the process of a given temperature. In the case of beamhouse work, the best possible temperature is that of the blood heat of the living animal, which with sheep is about 102° F., therefore for our purpose we shall endeavour to maintain a temperature of about 100° F. In order to effect this all the operations must be carried out in a stout wooden vessel and sealed. This is alone possible by adopting the drum as later described. The paddle wheel is totally unsuitable. *Volume.*—The volume of skins must bear such a relation to the liquid that the skins swim freely and are exposed to the action of the liquid at every point. There must be no balling or pounding of the skins. *Concentration.*—

The deliming agent bears some relation to the amount of free lime but not entirely, as is described later. The concentration depends upon the amount of pelt lime and the character of the skins. *Motion.*—The question of motion is of great importance. The speed at which the drum revolves should not be such as to pound and knock the skins about to their injury. The drum being half full of liquor and the quantity of skins about, say, 600 lamb skins, there will be approximately nearly two gallons of liquor to each skin. There is no crowding, the skins are each turned over and new surfaces presented to the liquor at each revolution, they open out, fold into folds, bend, squeeze, and perform all the possible operations of pressing and expressing. Every skin receives the same treatment, and it will be found that, provided the skins have been carefully graded for character prior to the operation, each skin will be reduced to an exact and similar state of flaccidity. This is not possible in a paddle wheel, because it is not possible to maintain the temperature throughout the process without disturbing the *concentration* by running in hot water; further, the skins do not tumble about as in a drum but swim round and round, the outer circles keeping together and the inner, moving at a slower rate, also keeping together, and frequently the skins form balls or lie resting in some corner and escape treatment. The inside rotating skins do not receive the same treatment as those which are revolving in the outer ring of the paddle stream, hence the results are variable in flaccidity. *Time.*—This is a factor which depends upon the desired results and to a large extent upon the management of the operator, but it should be clearly understood that, while the acid does not bear a relation to the amount of lime present, the pulling down factor is time.

Physico-chemical Beamhouse Work.—After liming the sheepskin, the flesh is removed either by hand or by machine, and then, should any hair be present on the shanks or flanks, it is removed over a beam with a blunt knife by scraping. The pelts are now ready for the wet-work operations to be carried out, the exact method being adjusted in detail to ensure the desired result being attained in the finished leather. Variations in the process must be made in accordance with the class of leather to be produced and the character of pelt handled.

In principle, taking the sheep pelt, it is usual to wash the surplus and free lime from the pelts in successive changes of water, either cold or tepid. The object is partly to economise bating material ; but such economy is open to question, especially in the light of our present knowledge of artificial feeding and cross-breeding, etc. It is assumed that, after washing out all free lime, there remains enough surplus lime in the pelt for the bating materials to act upon without destroying the natural chemicals in combination in the living skin. As to how far this washing should be carried must be left to the judgment of the beamhouse foreman, who will be governed by his experience and results, but in general practice it will be found that under modern conditions the washing has been in the past excessive. The question of economy in bating material should not weigh against the accomplishment of a given final result; such economy may be made in the beamhouse while the loss may be more than doubled in the finished product. The reader is here reminded of what has been described on pages 297–9, where the pelts were never washed at all and yet very excellent results were attained. It is not suggested that that process is in any way the best, but it does give cause for reflection upon current methods. If washing is performed it should be done with discretion, and every effort made to retain as much pelt substance as possible, the efficiency of the bating process being relied on to remove any free lime, etc.

The physico-chemical process, which will be described herein, employed to reduce the pelt to the state of flaccidity, is termed "pulling down," and is conveniently carried out in a specially constructed drum as follows: Build a drum of two to three inch soft wood planking, smooth inside, measuring internally eight feet in diameter by six feet broad. Instead of pegs or the ordinary flat shelves, place, about every two or three feet apart, shelves shaped approximately like the annexed drawing. The apex of the shelves is first made Gothic shape, then a strong oak peg is inserted down the centre of the apex to prevent splitting, and the apex rounded off; such shelves should be make of oak or other strong wood which will not splinter. The interior of the drum must



be entirely free from projections which may injure the skins, and the door must be one of the recent devices which are capable of immediate fixing without allowing leakage and without screws or other similar slow apparatus.

The drum is suspended on heavy trunnions, one of which has a hole provided throughout its length to the drum interior. Apart from the usual driving arrangements, the drum is provided with a suitable mechanical device for easily turning it, when occasion requires, by hand when full of skins and liquor. Underneath the drum and covering its entire area is a wooden cage about two feet deep, below which is a large drain to take away the liquor when emptying the drum. Such a drum requires to be driven from six to eight revolutions per minute. Opposite the door, when the drum door is halfway down between top and bottom, suitable pipes are placed to feed in hot and cold water with reversible nozzles. Such a drum when half full of liquor will contain approximately 1000 gallons.

If the drum is a new one it should be seasoned to acid by filling it with hot water, adding an acid of any kind, and revolving it until all the acid has been absorbed. The operation may be repeated until no further absorption takes place and the timber is seasoned.

The Pulling-down Operation.—Heat the drum with scalding hot water by filling, say, a quarter full and rotating it for a few minutes. It is important that the woodwork be heated in order that it should not absorb heat subsequently from the general body of liquor. Run the drum up until half full with water at 105° F., now add from a quart to half a gallon of formic acid 90 per cent. (other acids may be employed according to the preference of the worker, but the author prefers formic acid because it is the only commercial acid which brings lime into a clear solution; this fact may be demonstrated by any one taking equal volumes of clear saturated lime liquor, placing them in convenient glass vessels, and adding to each an equal amount of an acid, say to No 1, sulphuric; 2, hydrochloric; 3, butyric; 4, lactic; 5, acetic; 6, formic; and then noting the amount of deposit; it will be seen that in all except the glass containing the formic acid there will be varying degrees of deposit; the latter will remain quite clear, though the lime nevertheless has been converted into soluble calcium formate). Having added the requisite amount of acid, close the lid of the drum and revolve for a few minutes to ensure admixture, then stop drum and raise the door about a foot above half-way to prevent loss of liquid while adding the pelts. The pelts, to the number of 600 lambs, or less as they become larger, until 300 will suffice for large sheep, will have been previously washed up in a final water of about 105° F.; these are now as rapidly as possible thrown into the drum, the door sealed, and the drum at once set in motion. With lambs the pulling-down operation may last from twenty minutes to half an hour, but with old sheep the operation may endure for two to three hours. Let us suppose lambs are being pulled down, and they are what are termed milky lambs, then the amount of acid may require to be less than a quart, according to the amount of lime present and the amount of flaccidity required; if old sheep are being pulled down, then sometimes more than the half-gallon indicated may be required to attain the desired result; this must be left to the judgment of the operator, who will, at a suitable time, stop the drum and test the liquor for acid and the skins for feel, then, if more acid be required, he will add it, diluted, through the hollow axle while the drum continues to revolve. If the operator is doubtful as to the amount of acid required and feels nervous, he may prevent mischief by adding a small quantity of salt as a corrector, but experience on part of the operator, in studying the effect at first of a small quantity of acid and giving prolonged time, will enable him later to amend his judgment so as to use a minimum of acid and minimum of time in securing the desired results. It is not advisable to introduce any foreign agents into this process and the operator will secure the best result by learning to rely on his own judgment.

It is of the greatest importance that the temperature of the liquor in the drum should be maintained at or near that of blood heat. In course of time, about an hour or two according to the character of the skins, they will fall as flaccid as in the old method of dog puer, the amount of flaccidity is absolutely within the control of the operator. Immediately the skins commence revolving in the acid solution they become rough to the feel but should not swell.[1] After a time this roughness disappears and the skins begin to fall, and will continue to do so until taken out. The amount of flaccidity is determined by the feel, pinching the skins between the thumb and first finger and observing how far the flesh and grain are compressed together, and by cutting the thickest part of the neck (the mane) and applying a touch of phenol phthalein to the centre of the incision: it will be noted if it colours red that the lime has not been neutralised, if clear then the skins are lime free. After pulling down the skins are a beautiful white or cream colour with a fine feel. A further test of effectiveness of pulling down is to test the skins by taking a shank in one hand and drawing the skin through the thumb and finger of the other hand formed into a small ring. If the skin after drawing through remains *in situ* and displays no disposition to expand or show elasticity, then take it by the opposite shank and flank and pull it out as far as it will go; if the pulling down is complete the skin will remain extended to the length pulled. This is called in the glove leather trade "Stand" and is an excellent test for elasticity. Assuming the desired result has been attained, the door is removed and the drum revolved by the hand mechanism previously suggested, and the contents quietly emptied into the cage provided underneath from which they are removed to the scudding

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[1] Some users of the acid deliming method have not met with the success they expected and have charged the process with a too inordinate swelling of

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the pelt. This in experienced hands has been found impossible after the process has been mastered by gauging the exact amount of acid required to accomplish the "pulling down" act. Where inexperience exists, the danger of over swelling may be arrested by placing a "policeman" in the shape of common salt added to the solution. If commercial hydrochloric acid is used, then the "policeman" should be chloride of lime.

shop and laid down to drain straightened out in small heaps for a short period.

The drums used for pulling down must never be employed for any other purpose if economy is to be expected in material and results.

In carrying out this process it is important that the factors of heat should be maintained as near that of blood heat as possible ; the volume of skins or gelatine content plus lime should be the same ; the concentration reduced to accurate proportions ; the time given will vary according to the character of the stock, be it firm, rough, harsh, heavily limed, etc. ; and the motion should be regular and constant.

The Theory.—Broadly, the addition of any acid to an alkaline solution is to decompose the alkali to the salt of the particular acid, but in our case the total amount of acid does not bear any true relation to the total alkali present. Then to what may we attribute the pulling-down action ?

No simple and conclusive answer is possible, but it seems apparent that the extent and velocity of the reaction is dependent on the "active mass" of the acid, the process therefore provides an excellent example of Guldberg and Waage's Law of Mass Action.

It would appear we have a number of contributing factors, for even such chemically neutral bodies as calcium formate or chloride, sodium chloride, thiosulphate, etc., etc., exercise a falling or dehydrating action, and while doing so remove the elastic quality. Thus these bodies are strictly pulling-down reagents although they do not complete the deliming process.

Sufficient stress can never be laid on the importance of maintaining the temperature, as it is well known scientifically that reactions can be held up or even reversed by variations in this prime factor.

The very character of colloids seems to consist in the fact that there is a relation of cause and effect between the colloidal equilibrium of those substances and the chemical equilibrium of their constituent parts. With these particular chemical constituents, therefore, under the conditions existing at the temperature of life, slight variations in the colloid state (electrostatic and hydrostatic state, etc.) may intervene to set chemical reactions among those constituents, or even change the direction of reactions. In other words, the chemical constituents of the colloidal substance can be dissociated at a given temperature.

To take the example of the fundamental experiment of dissociation: Above 900° C. carbonate of calcium, contained in a vessel with carbonic acid, exists in equilibrium with those constituent substances, just as water in a closed vessel is in equilibrium with its own steam. Increase slightly the pressure of the enclosing surface without change of temperature, and the carbonic acid will combine with the lime to form a new quantity of carbonate of lime; diminish the pressure, on the contrary, or leave it unaltered and increase the temperature, and the carbonate of lime will dissociate itself into lime and carbonic acid. Every variation in temperature or pressure will thus be accompanied by a formation or dissociation of carbonate of lime; the chemical equilibrium existing between the compound and its composing elements will therefore be governed by the physical conditions existing within the enclosed surface. Hence we have chemistry and physics united by relations of cause and effect so inseparably as to warrant the employment of the term *physico-chemical.*

Scudding.—After pulling down comes this operation which consists in working the skins on the grain side either over a beam with a sharp semi-circular knife, or by a machine with knives radiating spirally left and right from the centre. These knives may be of steel, brass, slate, vulcanite, etc., as the case may be, but in all cases they work upon the skin which in turn is placed upon a soft cushion bed, generally of soft rubber; the only deviation from this rule is that of the Turney grain scudding machine which operates by means of rotating brushes working over a wooden cylinder. A convenient and simple means of conveying to a worker's mind the exact kind of edge required upon the scudding knife is to describe it as sharp, or like the edge of a hard-worn threepenny-piece, or a hard-worn sixpence, or a hard-worn shilling, or half-crown edge. The edge of the blades must be perfectly free from the slightest roughness to the thumb-nail when passed along the edge. If any roughness is present then it must at once be removed with an oil stone. The object of scudding is to empty the skin of what is called "scud," a rather too comprehensive trade term, as the various sections of the leather industry differ as to the exact meaning, but for our purpose, *i.e.* the sheepskin, the knife edge should be equal to a hard-worn threepenny-piece, the pressure should be light and the scud should consist of some fat, limesalts, wool follicles, the sebaceous glands contents, some gelatine and pigment from the wool. After scudding the skin should be drawn through tepid water to remove any adhering scud on the grain surface. At this point it is usual to place the skins in a bran drench in order completely to remove all trace of lime.

Bran Drenching.—The methods of drenching are so numerous and varied as to be quite impossible of adequate and full description, so no attempt will be made herein to give one, but rather to confine our remarks to certain criticisms and give recommendations for increased efficiency. As pursued in most tanneries, this operation is treated with scant attention so far as cleanliness is concerned, thus foreign bacterial agencies are introduced which cause unending trouble and loss. If it is to be effectually performed *absolute cleanliness must be observed* in all vessels in which the operation is carried out and attention given to minute details. It is essentially an operation which operates through the agency of certain bacteria which do not attack gelatine tissues, but operate in breaking down the bran chemical combination into other chemicals called acid enzymes, which in turn play a rôle, as we shall endeavour to describe later.

Drenching should never be carried out in wooden or similar vessels which may not be efficiently cleansed as clean as one's dinner plate. By preference pits should be built of brick with cement joints and coped with a layer of terra-cotta slabs rounded on the top. If the bricks are free from lime the joints should be made with Keen's cement. If not, then the pit should be well coated with boiled oil after drying, repeated again and again until no further absorption of oil takes place, or the pit may be painted with several coats of any cheap paint and finally varnished with a cheap hard varnish, or the sides and bottom may be painted with coatings of water-glass (*sodium silicate*) and dried, then the pits filled with a weak acid solution and left for an hour or so, dried again, and another coat of water-glass given. Such pits may be used for any operation which calls for the use of an acid, and in the last case where water-glass is employed the pit may be used for all purposes, as its walls and bottom will be coated with an impermeable glaze. On top of each pit a paddle is mounted, and, in the bottom, the rear and front angles of the wall with the bottom are shelved off with brickwork, sloped so as to round the bottom as much as possible; in one corner a plug hole is placed, which has a perfectly round orifice faced with a rubber ring, in which an elongated plug with a rubber outside surface and a fixed ring at the top is inserted; over this plug hole a brass plate well perforated is embedded in the brickwork to protect the skins from disappearing down the plug hole. During work the plug is pressed very gently into the plug hole to secure absolute non-leakage of the liquor, and if not pressed too tight it may be easily removed and held in suspension with a hook fixed at the end of an iron rod while the pit is emptying. After the pit has been emptied of a used drench liquor *it must be washed absolutely clean with repeated applications of hot water and scrubbed with a scrubbing brush, and the paddle also similarly treated* until it is as clean as a dinner plate. In all processes which depend for their action on given bacteria it is of the most supreme importance that absolute cleanliness should be observed in all things in order not to admit any foreign agencies which may overcome the active agents of the bran and thus produce effects not desired or contemplated. To give two illustrations of what is meant, all beamhouse foremen are aware that under certain atmospheric conditions the drench will " turn " and the skins swell up and vamp; this for some unexplained reason frequently happens during thundery weather or when it is very muggy; this is due to a foreign agency which has found its way into the drench owing to lack of cleanliness and, as the conditions are suitable for its development and operations, it overcomes the agencies which should prevail, thus producing another series of acids which cause all the mischief. If the pits are kept perfectly clean, and certain other conditions to be mentioned hereafter are observed, then the undesired alteration in the drench will *not take place.* To give another illustration of the evils of lack of attention and cleanliness:—some years ago, a sheepskin tanner in a small way of business called upon me with a few tanned skins which carried certain defects on the grain which he thought might be produced by bad fellmongering. The character of blemishes indicated that peculiar kind of grain disturbance which I have only seen in skins due to neglect in drenching. He explained that he made his drenches in large casks which he had purchased from local wine merchants; that, after a pack of skins had been drenched, the contents were emptied by turning the cask upside down, and a bucket of water dashed inside to remove adhering bran was all the cleansing the vessel received; then a new drench was made in the cask; this "make" took place each evening before closing time, no one attended during the night or from Saturday at 2 p.m. until 6 a.m. on the following Monday morning, to push the risen skins down. If a drench is made at blood heat it does not take many hours before the skins begin to rise to the top, and as others rise they accumulate and pack until they may, unless attended to, overflow the cask or pit, owing to the gas evolved. That is just what happened in this case; the exposed grain surfaces of the skins were covered with a thin film of gluten upon which the putrefactive organisms which are present everywhere in the atmosphere settled, the gluten dried with a fine external film, and, as the day dawned, the temperature of the air rose and the encased germs of putrefaction did their work of destroying the delicate grain surface; the mischief was more apparent on Mondays than on working week days, but some amount of mischief was to be seen every day, especially during the warmer weather. In consequence of the adoption of cleaner methods the trouble has not since recurred.

Wood, in his book "Puering, Bating, and Drenching," gives prominence to the damages produced by drenching, see pages 236–238. He names the damages as Acid "turning," Putrid "turning," Pinholey drench, and Spongy leather. Not one of these can be produced in a healthy drench, and are the product of carelessness in not seeing that the drench pits, etc., are kept scrupulously clean, with plenty of air in the drench house; and, so far as practicable, direct sunlight excluded. If the rules laid down herein are adhered to we shall hear no more of drench troubles. *Don't blame the drench, but the man!*

Bran drenching depends upon given cultures (organisms) for a satisfactory performance of its work, plus other considerations, as explained in the section discussing the theory. If the operation relies upon certain forms of life, then it will be readily seen and appreciated that those or that special organism, and no others or other, must find its way into the liquor to disturb the successful course of the fermentation, and this can only be done by observing the most absolute cleanliness in all things connected with processes involving fermentation.

We must not be led astray by the statement that the entire action of drenching is due to the products of bacterial action. It is well known that if bran is taken direct from the mill and placed in water and used immediately as a wash it is capable of removing lime from the hands; the knowledge of this fact is made use of by foremen and managers who desire to handle tanned skins after handling limed ones, in order to avoid staining the hands. Bran is acid.

In a drench there are countless millions of bran particles which when agitated act as so many scouring brushes upon the skin surfaces. The value of this function is of great importance, but complete advantage is not taken of it, owing to a too strict adherence to the old gaseous methods of drenching, or lack of agitation of the liquor.

The "silent" drenching, *i.e.* non-agitation by means of paddles but leaving the skins to rise up until they bunch, is much in favour with some beamsmen. Why would be difficult to explain, except upon the grounds of inherent conservatism. The rising is due to evolution of gases produced by bacterial action in the natural course of their duty in breaking up the bran, etc., into acid enzymes. This gas, or gases, play no useful part in drenching; on the contrary, it is very injurious to the *fatty layer*, causing it to separate, and producing grain blisters and pinholing by accumulating gas pressure in the sebaceous gland layer; the gas should be allowed escape freely. The evolution of a gas in drenching, while a necessary evil, should be classed as a tanner's enemy. In all cases, immediately a skin begins to rise, the whole mass should be paddled for a few minutes to release gas content, or, better still, as it will be shown that drenching proceeds apace during motion, by paddling the skins until the drenching act is completed, the gases will thus be released constantly. A considerable amount of destruction of the glassy skin surface takes place in the skin pockets in silent drenching which can be readily avoided.

Apart from the falling action produced by drenching, it does another important act. We have shown that lime restores the calcium salts in the skin; the drench restores the phosphate salts, possibly through the glycero-phosphoric acid developed. Phosphatic leather is one of the toughest leathers yet produced, and may be produced by any one with elementary chemical knowledge. The retention of phosphates in the skin is of vital importance.

A drenched skin absorbs a large quantity of *gluten* which if not subsequently removed by scudding will be precipitated within the skin by tannin and thus a fuller leather will be obtained. Gluten is precipitable by tannins, and saturated salt liquor.

In making up a drench no advantage is secured by scalding the bran or making up a hot or cold drench ; in general practice it will be found advisable continuously to paddle, or drum, and to keep the temperature about blood heat. The quantity of bran will vary according to the character of skins to be drenched. About a pound of bran per dozen lambskins and about one and a half pounds of bran per dozen sheep-pelts is a fair average. The more bran, the greater quantity of enzyme action with accumulation of gluten within the pelt.

The drench house should have a strong current of fresh air passing through to remove the gases, and the windows should be darkened or have non-actinic glass fixed therein. All direct rays of the sun must be excluded.

To scud the skins after drenching will remove the gluten content, producing thinner and looser leather.

In order to restore the chlorine content to the skin, they should be well salted out of drench, *i.e.* drench pickled. In all cases where the skins are salted, the first tan liquors must also be salted, but not necessarily the subsequent liquors.

If the advice given is followed and the following rules noted, it will be found that the lost natural salts of the skin due to the wet-work disturbances have been restored so far as our present knowledge admits, and the final results in finished leather will be more regular and consistent, with a decrease of many faults which as yet await an explanation in most tanneries.

1. Use specially prepared pits for drenching, and never use them for any other operation.

2. Observe the most scrupulous cleanliness in every act connected with the drenching operations, even to cleanliness of person.

3. Exclude all actinic light and give a free current of air through the drench house.

4. Prepare all drench liquors at one temperature.

5. Avoid silent drenching, and test the value of agitating the drench constantly until the drenching act is completed.

6. Place a value upon bran as a scouring agent and detergent.

7. Give some attention to results to be attained from including the gluten within the skin as a filler in tanning.

8. Do not neglect the value to be attached to the successive operations in restoring the natural salts of the living skin.

9. Time, experience, and expediency has proved the value of pickling after drenching.

10. Do not fail always to introduce the salted skins into a salted tan liquor first and if necessary fresh tan liquors subsequently.

Pulling down and Drenching with Bran Infusion.—For nearly all purposes of puering, bating, pulling down, and drenching, the operations may be combined with advantage and reduced to a simple treatment, having none of the disadvantages of the several methods and offering considerable advantages over all other methods. It is capable of removing the beard from a goat-skin or breaking down the most stubborn and hard pelt to a condition of complete flaccidity. The word "beard" is that condition which is frequently felt on goat-skins after dehairing, and resembles the unshaven face of a man when rubbed with the hand. This method of pelt cleansing and reduction I strongly recommend to the attention of all workers who are seeking for an ideal process of wet work.

In order to carry out the process successfully, it is necessary to build a similar drum as that recommended for pulling down. After heating the drum as previously suggested in order to bring the temperature of the woodwork of the drum up as near as possible to that of the liquid content, run in sufficient water at 105° F. until the drum is half full, to this add about 50 to 60 pounds weight of bran. The pelts having been previously washed in a final water of about 105° F., about 600 lamb-pelts, or less, according to the size, are thrown into the drum and at once set in motion. They should be examined from time to time; no further quantity of bran requires to be added, but care should be observed to maintain the heat at near to that of the blood. In course of an hour or so, the skins will fall quite flaccid and answer all the tests applied. When they are ready for scudding it may be advisable to give them a slight washing in the drum by running water through the hollow trunnion after placing a perforated door in place of the water-tight door. The washing may be carried out until the water runs clear or such times as the operator desires. The more the washing the less amount of scud will be present for removal with the knife, and it should not be forgotten that excessive washing will remove the gluten within the skin. In general practice it will be found advantageous to empty the skins from the drum after completing the operation and then scud them ; this will of course remove much of the gluten present, which if left in will increase the substance of the tanned pelt. In all cases the salting should be carried out before tanning. This applies to all classes of leather and all tannages.

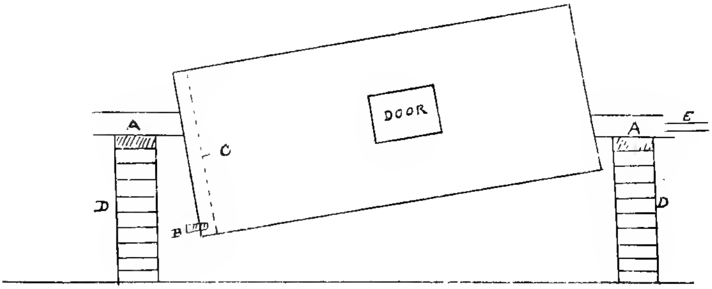
It may be found that in some cases the total lime is not removed, then it is recommended to give the skins a further quantity of bran in the drum for a short period after scudding and prior to salting. Skins treated by this method, which is in every respect hygienic, are tougher than by any other process, possibly for the reasons previously suggested as to restoration of phosphate salts.

This process has been made use of in such extreme cases as buffalo hides, which are by nature rough, coarse, and harsh, and considered by European tanners as unfit for dressing leather purposes. In the Eastern countries such hides are used for all kinds of dressed leather and are treated as follows (it must be borne in mind that in the Eastern countries the atmospheric temperature seldom falls below that of the blood and frequently rises in the shade as high as 120° F., hence it is not necessary closely to adhere to the methods prevailing in the colder lands) :—

The drum is open-sided with inch holes studding the whole of the periphery area. The hides are introduced through the sides. The drum dips into a tank about two feet or more containing a bran infusion or the like, the temperature of which is approximately that of the surrounding atmosphere. The hides, after a mere apology for washing, are introduced into the drum which is set revolving, and the pulling-down action proceeds apace, being finally accomplished after a few hours. The effect of this treatment upon such hides is really wonderful, the grain previously rough and harsh is reduced to a condition equal to that of a puered skin and the hide texture is flaccid. This process, subject to adjustment to our climatic conditions, may with advantage be applied to kips, buffalo, goat, and other harsh, beardy skins.

Pulling down Grains.—The same processes are applicable to split sheep grains, subject to an alteration in the construction of the drum; although the same style of drum may be employed it will be found advantageous to build a special drum for the purpose, called an "Oscillator drum," which, by its peculiar mode of hanging, gives to the contents a motion something like the figure 8.

The Oscillator Drum.—The drum may be conveniently made about eight feet long and about five to six feet in diameter. The exact angle of inclination is optional. It should be built of any soft wood, but perfectly smooth inside. The two walls D must be built in cement, and through them to a firm block of concrete two strong steel rods must be fixed in each wall and bolted through the timber which forms the bed plate for the trunnions AA. As there is some side thrust the walls DD should be secured to the rear wall. The right-hand trunnion should have the centre bored to admit the pipe E for feeding in any liquor. The left end of drum must be provided internally with a false end C, to admit of the liquid flowing out of the plug-hole B when required. Such a drum if suitably geared requires but small power to rotate, and will be found excellent in use for many purposes. If the pipe E is attached to a hot and cold water supply, the drum may be used for washing or soaking as well as pulling down.



It is important that the interior of the drum shall be *absolutely smooth without any projections even in the door* or the delicate goods may be torn. In this drum the treatment is exactly the same as has been already described for pulling down the whole skin. It is usual to scud grains after puering either with a Turney brush machine or by hand on the flesh side. In view of the evidence given as to the effect of artificial feeding upon the character of the *fatty layer*, it is worth testing the following method :—

Well wash grains in the oscillator and scud them in the washed state out of warm water on the grain side only, then proceed with the pulling down with formic acid, to be followed by drenching in the usual way, or they may be pulled down with bran drench; in either case, after drenching, they should be well salted in a saturated solution and the first sumac liquor should also be salted, but the final sumac liquor should be strong and fresh. The advantages of this method are many, the tanned skivers are very soft, and of a creamy white colour, with kind feeling grains, they pull out like glove leather, and will, in spite of the artificial feeding, be fuller in substance than the puered skivers; the time is shortened, and more reliable results are attained with a less expenditure. *The scudding of grains on what is termed the flesh side* (*the fatty layer*) *should be avoided if substance is a consideration.*

The object of scudding grains on the *fatty layer* is to remove the grease. This it only partially accomplishes, as witnessed by the fact that, in spite of the claim, skivers are still found greasy after tanning and are subsequently degreased with petrol ether. To remove the grease implies that all the fat lobules have had their cell walls broken and the grease content freed from its bonds. The grease problem must stand on its own merits and not be confused with any other operation, although it is quite possible to employ pancreas and steapsin or lipase for bating and the removal of grease under certain conditions. This phase of the grease problem is being worked out and there are bates on the market which contain these properties and in their way are useful. In India the natives use fermentations of *Babul pods* (*acacia arabica*) for bating. It is worth calling the attention of scientific investigators to the value of the *castor oil seed*, which is rich in *lipase*, for the purpose of producing a bate which will create oils and fats by hydrolysis to a glyceride of ricinoleic acid. In the production of any artificial bate the compounds of ammonia should be avoided, as they are apt to cause a harsh grain after tanning.

A Method for Degreasing Pelts.—As has been already pointed out, the sheep skin contains an unusually large amount of fat, which may or may not be equally distributed in a healthy state, or may be deposited as dead fat. The process herein suggested is open to many modifications in the hands of an experienced worker, and, for the purpose of a detailed description, I will take the question, a by no means easy one, of degreasing a dead fat or colty sheep pelt, leaving the alterations and adaptation of the process to the ingenuity of the operator.

After scudding, select out all the colty skins for special treatment as follows: Into a paddle pit, which has been well coated with repeated coats of paint or boiled oil and varnish in order to prevent absorption of the weak acid, run in a known volume of cold water, to which add from 0·25 to 0·5 per cent. of formic acid; plunge up the pit to ensure admixture, then put in as many skins as the pit will conveniently hold, bearing in mind they are to swell up and finally take up a greater space. After suitable paddling leave them to rest over night or until such time as they may have become equally swollen all over, and feel firm and solid as though they had been in a strong lime liquor, *but not vamped or bloated into creases or ridges.* It will be found advantageous to paddle them occasionally to redistribute the skin surfaces. It is essential to the success of the operation that the acid should be *very weak* and plenty of time allowed for the weak acid to draw a greater volume of water into the skin, bearing in mind that, although the skin may be swollen, it is requisite to give additional time for the fat cells likewise to swell equally and rupture, which they will do. The acid is simply employed to make the skins hungry for water, and that hunger is proportionate to the amount of acid used. When the operation of swelling is satisfactorily completed transfer the skins to a bath of hyposulphite of soda as saturated as may be conveniently made. The degree of saturation will depend upon the amount of grease content, but, as we are dealing with an extreme case, the hypo bath should be saturated and the temperature about 100° F. The skins are put in quickly and rotated for a short while to open them out, then allowed to rest for twenty-four hours. *It is important that the whole process should not be hurried.* When completed, the skins may be again scudded or passed through suitable rubber rollers under pressure, when the converted grease content will be expressed with facility. If the ultimate destination of the skins is for dull leathers, then the skins do not require expressing and it will be found (even with chrome tanning such as motor clothing) that the grease has been suppressed and will not appear exuding subsequently.

It is not perfectly clear as to what are the exact reactions here carried out, but it would appear that the result is the formation of a sodium sulphur soap which on drying appears as an insoluble dry powder which does not interfere with any subsequent operation of leather dressing. It will be noticed, too, by the observant operator in the tannery that skins, so treated, will absorb tannin at a greater and quicker rate than untreated skins, and therefore should be differently handled in the tannery.

The Rationale of Drenching.—The factors comprising the action of drenching are so numerous that any simple classification of them and their functions is as yet absolutely impossible. We know so little about the inner mechanism of the wet-work processes, that it is with some misgivings that we venture to propound theories on the rationale of drenching; nevertheless, it seems essential that a provisional hypothesis should be put forward, and either confirmed or confuted. Let us, therefore, briefly inquire into the actions which go on from the time the skin is immersed in the bran infusion until, by immersion in the next liquor, all reactions derived from this source are arrested.

The possible factors in drenching may be conveniently divided into three classes, viz.:—*mechanical*, *physical*, and *chemical*. These three are so intimately associated and co-related by recent scientific work that it may, perhaps, appear scarcely in accordance with the already published results of the latter so to differentiate them; but, while it is frequently impossible to decide where one ends and the other begins, there remain certain reactions which appeal to our minds as purely chemical, purely physical, or purely mechanical.

All the older theories have attributed a purely chemical action to the drench liquor, and it will be convenient to study this aspect of the question first. Such action may arise from the following conditions :—

(*a*) By the neutralisation of the base, lime, by the organic acids which we know to be present.

(*b*) By Double Decomposition or Quadruple Equilibria, whereby the salts existing in the liquor may interact with the calcium hydroxide with the formation of soluble calcium salts, *e.g.* the action of ammonium chloride to form calcium chloride.

The first of these, neutralisation, we know to play a big part in all drenching processes, the acids being, of course, derived from bacterial and enzyme action on the glucosides of the bran. A point, however, which has escaped most observers is that the basis of this acid liberation is a somewhat slow hydrolytic enzyme action, for it is common knowledge that any acceleration of the process by changes in atmospheric conditions, possibly electrical in their nature, tends to produce butyric acid and its isomers, to the great detriment of the immersed goods. The author has good reason to suspect that such "souring" of the drench is due to the enzyme of an enzyme, whereby the former, acting saprophytically on the latter, produces a disturbance akin to disease. Under cleanly conditions the original enzymes remain healthy, consequently no secondary enzyme action can take place, with the result that souring of the drench becomes unknown.

With regard to the actual neutralisation process, interesting physico-chemical theories present themselves for consideration. The acids produced from the glucosides are of the simple aliphatic type, and are said to be mainly the earlier members of the acetic acid series, namely, formic, acetic, and propionic acids. Most writers also claim the presence of lactic acid ; but A. N. Palmer, working under the direction of the author, was unable to identify this acid in any of the numerous liquors examined by him. This at once gives a clue to a very interesting possibility. Lactic acid is a hydroxy acid, and the liquors examined by Palmer had been produced under conditions of the strictest cleanliness, and it therefore seems possible that this and other hydroxy acids are the products of the before-mentioned secondary enzyme action. If this be indeed the case, it would seem probable that butyric acid has been unjustifiably blamed for the "souring" of the drench, for it is a common scientific fact that the introduction of certain radicles into the fatty acid molecule will transform the feebly ionising and "weak" fatty acid into an acid of high percentage ionisation. An analogous case is that of benzene-sulphonic acid, which is one of the most highly ionised acids known. The effect of the substitution of such an acid for, let us say, acetic or propionic, would amply account for the destruction of the goods during "souring."

It has been stated that the acids of a clean drench are feebly ionising, and this must be regarded as specially fortunate, as the base they have to neutralise, calcium hydroxide (lime), is a limitedly soluble, feebly ionising base. Thus the action between the two is enabled to proceed very nearly, but not quite, to completion. This is again a special dispensation, for it would now seem to be essential that the finished sheepleather should contain a modicum of calcium salts.

Another aspect of the question is the undoubted formation of definite chemical salts between the collagen of the pelt substance and these organic acids, for Procter has shown that highly ionising and highly hydrolising salts of the type, gelatine acetate, are formed during the drenching process. A most important application of Professor Procter's great work will undoubtedly be in connection with this chemical side of drenching; for it would seem possible that a properly drenched skin should be ultimately a mixture of definite collagen salts, whereby the correct degree of flaccidity has been imparted to the skin.

In regard to the Double Decomposition aspect of drenching, considerably less is known, but from work carried out by the author it would appear to be not the least important factor in the process. The use of ammonium chloride is of fairly ancient date, but there cannot be the least doubt that the energetic of the process is in no small measure facilitated by the establishment of a Multiple Equilibrium between calcium hydroxide and the salts of the liquor; for by this means the insoluble lime becomes dissolved and is thus brought within the range of physical and mechanical forces.

Let us now consider the physics of the process. The important factors in the physical state of the drench liquor are :—

(*a*) The Temperature.

(*b*) The Concentration of the electrolytes in the liquor.

(*c*) The Degree of Ionisation of the electrolytes in the liquor.

(*d*) The Size of the bran particles.

(*e*) The Electrical Condition of the liquor and possibly at times also that of the atmosphere.

The question of temperature of the liquor has been fully discussed elsewhere, and we are thus left with the other four factors to delineate the physical conditions of the liquor.

It is advisable to discuss under the same head any mechanical action which takes place. Practical men have for many years maintained the conception, that the actual solid particles of bran exercised a direct scouring action on the hide fibres, removing lime and dirt. It is difficult to imagine how such an action could take place under conditions of quiescent drenching, but there would certainly appear to be some scientific and practical grounds to justify such a belief. The action of the bran particles must, however, be attributed to the electrical conditions of the liquor, and it will be necessary to elaborate what, for want of a better term, we may describe as the "Adsorption Theory of Drenching."

The bran particles in a fermenting infusion of bran, if brought under the influence of a strong electrical field, will rapidly migrate to the negative pole, thus demonstrating that they are carrying a fairly strong positive electrical charge. In addition, it may be observed microscopically that they exhibit strong Pedesis or Brownian movement, from which they would appear to possess considerable molecular energy. A strong electrical charge means considerable free surface energy, and the little bran particles should therefore be strong adsorbents. Furthermore, the hide fibres in acid solution, such as exists in the drench, carry a strong positive electrical charge, and also by their enormous surface exhibit considerable free surface energy, and would also appear to be a fair adsorbent.

Turning to the other side of the question, we have calcium hydroxide in the finely divided condition carrying a negative charge by reason of adsorbed hydroxyl-ions. This negative calcium-hydroxide would appear to form a strong adsorption compound, or a weak chemical compound with the positive hide fibre prior to the drench. It is not, therefore, an unreasonable conception to regard a small part at least of the drenching action as a substitution of a hide-lime adsorption compound for a bran-lime adsorption compound. Indeed, we have all the necessary conditions for the promotion of such a change, as it may be easily demonstrated, that finely divided bran has in acid solution a more powerful Brownian movement than has finely divided hide substance; thus demonstrating that the former has greater available molecular energy than the latter. It is, therefore, not an inconceivable hypothesis to imagine that the material with the greater available molecular energy should eject and replace the one with the less. This is a simple adsorption theory of drenching.

The ideas briefly set forth in the foregoing pages, while based on considerable experimental evidence, do not claim to be more than provisional and withal conceivable theorems. It is hoped that any one disagreeing fundamentally with these propositions will lose no time in adducing such experimental evidence as is at his disposal for their confutation ; for only by such means can we increase the sum total of human knowledge on this or any other subject.

APPENDIX.

THE BACTERIOLOGY OF THE LEATHER INDUSTRY.

By J. T. Wood.

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Perhaps the earliest paper dealing with the part played by Bacteria in the leather industry in a scientific and practical manner was that of Eitner, entitled "Antiseptics in the Tannery" (der Gerber, 1889), in which he deals with it from the point of view of the prevention of injurious fermentations. In 1894 I published a general paper entitled "Fermentation in the Leather Industry," setting forth what I knew of the subject up to that time, and indicating some of the problems which were awaiting solution.

Since that date much important work has been done, especially in the bacteriology of tan liquors by Andreash, 1897, of drenches by Wood and Wilcox, and of bates by Becker and Wood, and quite recently my friend, Dr. George Abt, has published a general paper on the part played by bacteria in the putrefaction of skin and in the bates.[1]

Since putrefaction is the most obvious danger to the raw skin it is necessary to say a few words about it. Nearly all bacteria can be cultivated on nitrogenous organic matter (the nutrient gelatine of the bacteriologist has become an article of commerce) so that there is scarcely any species of bacteria which cannot take some part in the putrefaction of skin. In an article on "Recent advances in the Bacteriology of putrefaction"[1] I have given a short account of the researches of Tissier and Martelly on the putrefaction of meat, and it is probable that the putrefaction of skin follows much the same course. Abt (*loc. cit.*) gives the following table resuming the action of putrefactive bacteria.

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[1] (Le rôle des microbes dans la putrefaction des peaux en poils et en tripe dans les confits.)—Bull. Syndicat Gen. Cuirs et Peaux, Nov. 10, 1908, 416.

Aerobic	Mixed	Proteolytic:	*Micrococcus flavus liquefaciens, Proteus vulgaris,* White *staphylococcus.*
		Peptolytic:	*B. Coli, B. filiformis, Streptococcus pyogenes, Diplococcus griseus.*
	Simple	Proteolytic:	*B. subtils, B. mesentericus.*
		Peptolytic:	*Proteus Zenkeri.*
Anaerobic	Mixed	Proteolytic:	*B. perfringens, B. bifermentans sporogenes.*
		Peptolytic:	*B. bifidus, B. Lactopropylbutyricus non-liquefaciens* (*Tissier*).
	Simple	Proteolytic:	*B. putrificus, B. putidus gracilis.*
		Peptolytic:	*Diplococcus magnus anaerobius, B. faecalis alkaligenes.*

The simple ferments are those which are capable of fermenting nitrogenous matter only, the mixed ferments are able, not only to ferment nitrogenous bodies, or proteids, but also to act upon carbohydrates, such as sugars and starches, from which they produce organic acids.

The proteolytic bacteria which begin the action are those capable of liquefying, and afterwards decomposing the natural albumins. The peptolytic bacteria are those which are only able to attack the soluble products of the decomposition brought about by the former, so that it is clear the peptolytic organisms remain without action on a sound skin, but will be able to complete the attack begun by proteolytic organisms.

In a normal putrefaction the different groups of bacteria follow one another in regular order. At the beginning we find mixed aerobic organisms; first proteolytic, then peptolytic, they produce acids, principally amino-acids of the type of leucin, which are soon decomposed with production of amines and ammonia, so that the acidity is gradually neutralised. At the same time, the aerobic bacteria have used up all the oxygen of the material, and prepared the way for the mixed anaerobic bacteria. At this stage the putrefaction becomes rapid, and the production of ammonia is sufficient to render the mass alkaline. The simple anaerobic organisms now appear, *B. putrificus*, *B. pudidus gracilis*, and *diplococcus magnus*. The complete cycle may take several weeks.

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[1] *Journal of the Society of Chemical Industry*, 1906, 109.

The most important putrefactive organisms are probably *B. putrificus*, and *B. putidus gracilis*, which are anaerobic, and can only live in an alkaline medium.

It may be noted that the skins in their fresh state contain all the bacteria which develop later, and which cause putrefaction, but the putrefaction only begins when all the conditions are favourable. There is no doubt that the first stage—the solubilisation and peptonisation of the nitrogenous matter—is the most difficult, but once this has begun the fermentation soon reaches the stage at which ammonia is evolved. We see, therefore, that to preserve the skins it is necessary to prevent the presence of dissolved albuminous matter. The simplest method is that of drying the skins, and if this is properly done, it is quite effective in preventing bacterial decomposition, and in order to prevent the attacks of higher organisms such as mites, insects, and worms, the dry skins are strewn with napthalene before being packed into bales. The other usual method of preserving skins is by means of salt. This also prevents the development of bacteria by dehydrating the fibre of the skin. There are some bacteria able to grow in the presence of salt, one species of which produces a colouring matter which it is impossible to remove from the skin, and which is one of the causes of the defect known as salt stains. The study of this defect, so far as I know, has not been made, and I might suggest this as an interesting and useful research. (Lantern slide.)

There are very few poisons that actually kill bacteria, and at the same time are without action on skin. Corrosive sublimate, chlorine, and bromine will kill them, but in practice the use of such substances is not possible, or even necessary, if due attention is given to the working. The use of a solution of arsenic in caustic soda has been tried, but has not been entirely successful in practice, owing to the fact that the main action is due to the soda; the arsenic has practically no detrimental action on the bacteria. Trotman found that *Bacillus subtilis* is not killed by arsenic solutions of the strength recommended. In some cases it actually continued to develop in the solution. Formaldehyde is a powerful and effective antiseptic but it has a tanning action on the skin which prohibits its use as a preservative. Since formic acid has become a cheap commercial product a good deal of attention is being paid to its use as a preservative for skins and Mr. Seymour-Jones has described its use in the pickling process.

At the present time the I.A.L.T.C. have formed a Committee under the presidency of Mr. A. Seymour-Jones, to deal with the preservation and curing of raw hides and skins with the object of reporting upon and standardising various methods in use.

The chapter on antiseptics and disinfectants in Procter's "Principles of Leather Manufacture" is very complete as a reference to this subject.

I cannot leave the bacteriology of raw skins without saying something of anthrax, which is sometimes conveyed by bacteria contained in the skins and hair. This was one of the earliest diseases which was proved to be due to a specific organism (*Bacillus anthracis*, Davaine, 1863) growing in the blood of the animal infected, and capable of being cultivated on nutrient media outside the animal's body, such a culture inoculated into the blood of a healthy animal was found to produce the disease in all its virulence, and the bacteria were again found in the blood.

The anthrax bacillus is in the form of short rods very like

B. subtilis, but as its characteristics may be found in any book on bacteriology, I shall not describe it further than to say that the chief reason it is so dangerous is its capability of forming very resistent spores, which remain capable of developing after years when again placed in favourable conditions. These spores are found in the dirt and dust of wool, horse hair, and hides of animals which have died of the disease. In this country anthrax among animals is rare, but in Russia, China, India, and many parts of the world the disease is common, and infected material is often shipped to British ports. Wet salted hides and greasy wools are free from dust, and little risk is incurred in handling them. The disease is communicated to man sometimes by breathing or swallowing the dust, but more usually by the poison lodging in some point where the skin is broken, such as a fresh scratch, or cut, or a scratched pimple, or even chapped hands.

Dr. B. A. Whitelegge, of the Home Office, from whom I have taken the above remarks, has prepared statistics of cases of anthrax caused by various industries, from which I have abstracted the following table for the five years, 1902—1906 :—

Industries.	Cases.	Deaths.
Wool sorting	15 = 5·7 %	4 = 5·6 %
Wool combing	87 = 33·5 %	24 = 34·0 %
Handling horsehair	46 = 17·5 %	12 = 17·0 %
Handling of hides, tanning, fellmongering ...	77 = 29·5 %	20 = 28·2 %
Other industries	36 = 13·8 %	11 = 15·2 %
Total ...	261 = 100 %	71 = 27 % of total cases.

It will be seen that the most dangerous cases are those occurring in wool combing, where there were 24 deaths in 87 cases. The next most dangerous occupations are handling of hides, tanning, and fellmongering, where there were 77 cases and 20 deaths. It would seem from these figures that the breathing in of infected dust is more fatal than inoculation from a scratch.

In connection with this disease, Dr. Turnbull, of Liverpool, tells me that the gloves which are worn by the men handling hides are liable to become a source of infection if not disinfected or sterilised regularly, as the sweat from the hands causes them to become dirty and form a nidus for various kinds of organisms.

The Committee of the I.A.L.T.C. for the preservation and disinfection of hides and skins which I have previously mentioned has also this part of the subject under consideration, and Dr. C. Ponder, of Cambridge, has been appointed by the Leather Sellers Technical College to investigate anthrax. It may be of interest to mention that the anthrax cultures now being used by Dr. Jouan at the Pasteur Institute, are descended from the original culture isolated by Pasteur himself thirty years ago.

The Soaks.—The first process through which the raw skins go on reaching the tanner is the simple steeping or washing in water, known as the soaks. In the case of fresh skins coming from the markets a short immersion in cold, running water is sufficient to get rid of blood and dirt, and the skins have not time to undergo any putrefaction. In the treatment of salted skins the water quickly dissolves out the salt, and if mechanical means (paddle or drum) are used, there is little or no danger. It is in the soaking of skins previously dried, which takes several days, that the danger of putrefaction arises. At one time the deliberate use of putrid soaks was in operation, but in the modern methods, where no chemicals are used, one fresh water is given to each pack of skins. Even in this case, considerable putrefaction (by putrefaction I do not mean actual damaged grain, but include simple solution of skin substance under this head), and consequent loss of skin substance, takes place where the soaking occupies seven days or more. The bacteria of the soaks are numerous and varied, and even at a temperature of 5° C. a single loop from a comparatively fresh soak will develop so many colonies of liquefying bacteria in a gelatine plate as to quickly liquefy the whole plate. A rise in temperature of a few degrees is sufficient to double the number of organisms; it is, therefore, imperative, to keep the temperature of the soaks as low as possible; it should not exceed 10° C. So far as I know, the bacteria in the soaks have not been especially investigated except by Andreasch, who found the following species:—

Bacillus fluorescens liquefaciens (Flügge), *B. megaterium* (de Bary), *B. subtilis*, *B. mesentericus vulgatus*, *B. mesentericus fuscus*, *B. mycoides* (Flügge), *B. liquidus* (Frankland), *B. gasoformans* (Eisenberg), White bacillus (Maschek), ***Proteus vulgaris***, ***Proteus mirabilis***, ***Bacillus butyricus*** (Hueppe), White *streptococcus* (Maschek), Wormshaped *streptococcus* (Maschek), Grey *coccus* (Maschek). All these may be classed as putrefactive organisms, and some of them act energetically on the hide substance. The slide shows a typical plate culture on gelatine of a soak used for softening dry sheep skins, in which no chemicals have been used. The development of the colonies has had to be stopped by the application of formalin vapour before many of the species have had time to develop, otherwise the whole plate would have been liquefied. From what has been said, it will be seen that the most suitable mode of preserving skins, by which the least risk will be run in subsequent operations, is the salting process, or some modification of it. We have seen that the species of bacteria developing in the soaks are mostly putrefactive, and, therefore, injurious bacteria, and I do not think that any useful purpose to the tanner would be served by a research as to the nature of the organisms developing. The line to be followed here is to work out the best method which will prevent the development of bacteria in this part of the work, that is, the soaking should be carried out, as far as possible, under antiseptic conditions.[1]

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[1] The use of various substances in the soaks to prevent putrefaction has been tried. The best of these is a solution of caustic soda, one part per thousand, or of sodium sulphide 1½ to 3 parts per thousand. Forty-eight hours in either of these solutions is sufficient to soften most dried skins, while putrefaction is almost entirely prevented, and the soaking may be conducted without danger at temperatures up to 18° C. (*Vide* Procter, *Principles of Leather Manufacture*, p. 114).

Depilating and Liming.—After soaking the hair or wool must be removed from the skins. This is usually done in the case of hides by immersion in lime water, or milk of lime, until the hair slips, and although lime is an antiseptic, we shall see that even in this process bacteria play an important part. I shall pass over the depilating of skins with sulphides, and sulphur compounds, which loosen the hair by dissolving the epidermal tissue, because in this case bacteria take no part.

Both hides and sheepskins are frequently unhaired by the process known as sweating, in which the wet skins are hung in a moist chamber (the sweating stove) at a temperature of 15° to 20° C., partial putrefaction commences; ammonia is evolved, and in four to five days the hair or wool may be easily removed. Procter finds that the vapour of ammonia alone is sufficient to loosen the hair, but in sweating, the prime cause in the solution of the epidermal tissues surrounding the hair roots by bacteria, or rather, by digestive enzymes produced by bacteria.

Villon was the first to describe the organism which attacks the albuminous matter at the hair roots; he calls it *Bacterium pilline*, and describes it as an aerobic organism which decomposes pilline, transforming it into leucin, tyrosin, butyric and margaric acids, and sets free ammonia, which dissolves the coriin, and thus sets free the hair. From the description given it is very doubtful whether Villon's bacterium was a pure culture, although he considered it to be so.

Villon's experiments have been criticised by Schmitz-Dumont (15), who describes the specific depilating organism as a streptococcus, which by decomposing the rete malpighi loosens the hair. Schmitz-Dumont's experiments are little more convincing than Villon's as to the sweating being caused by a specific organism, the difficulty being to sterilise the skins without injury. I have examined the bacteria from the roots of wool in a sweating stove used for depilating sheep skins, and have isolated several organisms, among which are the bacteria described in a former paper[1] as *bacillus* D. & E.

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[1] *J.S.C.I.*, 1899, p. 990.

(Fig. 3). I also found *B. fluorescens liquefaciens,*[1] but I have not made an attempt to ascertain whether one of these alone, or all of them, are responsible for the unhairing process. I found a similar organism to *bacillus* D. in old limes; all of these produce ammonia from organic nitrogenous matter, and are capable of living in a strongly alkaline medium, even of higher alkalinity than a saturated lime water. Probably one of these organisms is the same as the bacteria of Villon and Schmitz-Dumont, but in my opinion it will be found that the action is produced by a simultaneous growth of several different species of a bacteria.

Procter states that an old lime becomes charged with ammonia and other products of the action of lime upon skin, such as tyrosin, leucin, and some caproic acid, but so far as I am aware the mode of production of these bodies is still unknown, and it seems doubtful whether ammonia is produced in the cold in a sterile lime. In the case of the sweated unlimed skin, we know that the ammonia and alkaline bodies are produced by the action of bacteria on dissolved skin substance, and it is highly probable that the same kind of action goes on in the limes, and that it is produced by the same bacteria. The fresh lime dissolves the interfibrillar substance of the skin,[2] bacteria obtain access from the air, then decompose the skin substance with the production of the bodies named. That this is so is supported by the statement that in Payne and Pullman's liming process, in which the skins are first treated with caustic soda, and afterwards placed in a solution of calcium chloride, they cannot be unhaired unless they have been previously acted upon by putrefactive bacteria, that is, the skin can be limed with the hair on, and this fact has been made use of in the preparation of fur skins.[3]

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[1] B. fluorescens is not invariably present, but there is some organism which produces a dark grey colouring matter, and which eventually overgrows the depilating organisms.

[2] See the amount of skin substance dissolved in fellmongers' collecting limes. Wood and Trotman, *J.S.C.I.*, 1909, p. 1304, where a lime was found containing 3·37 grms. skin per 100 c.c.

[3] As a matter of fact, Payne and Pullman's process of liming sterilises the skin, so that the depilating bacteria cannot grow.

This would seem to be an additional proof that the loosening of hair in the limes is brought about by the same means as the unhairing in the sweating stove, though, in the latter case, real putrefactive bacteria are liable to attack the skin, whereas in the limes the skin is preserved from the action of these putrefactive organisms.

Payne, however, states that hydrosulphide of lime is produced by the action of caustic lime on the sulphur in the hair and that this has an unhairing action. In this case a sterile lime should unhair. I believe it will do so if time be given for the chemical action to take place. That this is a slow process is the probable explanation of the failure to unhair which has been observed in Payne and Pullman's process.

There is no doubt that the growth of bacteria in the limes is one of the principal factors in the "mellowing" as we call it. Griffith (J. Amer. Leather Chem. Assoc., 1910, 5, 109—129) states that the mellowness of the used lime liquor may be artificially produced by the addition of ammonium sulphate to the limes.

There is a form of damage, which principally affects sheepskins, known as "lime speck" (Fig. 2), and which is due to a colony of bacteria forming on the grain side of the skin just below the hyaline layer. When lime is applied to the skins by the fellmonger, in order to remove the wool, a portion of it becomes fixed in the colony in the form of carbonate, and partly as a combination with the fatty acids from the wool roots. Possibly there is also some combination of lime with the skin substance, which has been liquefied by the bacteria.

True lime speck, so far as I know, is never caused after the wool is removed, by sulphide or by lime only, although it is stated that it sometimes occurs in sweated skins. It may be classed as a putrefactive damage, and can be avoided by keeping the skin in a sterile condition until it is ready for painting. A further investigation of this defect is necessary, and would be very useful.

I have already suggested (*J.S.C.I.*, Nov. 30th, 1903, 1274) that the rôle of bacteria in the liming process should be worked out in our research laboratories in the same way as the bacteria in the tan liquors, bates, and drenches have been investigated by Andreasch, Becker, and myself. From what has been said it will be evident that the species to be isolated in this case are much less numerous than in most other parts of the tanning process, and the work should demand a proportionately less time.

Bating and Puering.—The next process which the skins go through before passing into the tan liquors is to remove the lime, and give the desired character to the leather. Sole leather must be firm and dense, it is, therefore, usually sufficient for the surface lime to be removed by washing or handling in soft water, the natural acidity of the tan liquors dissolves the remainder of the lime.

Light leathers, which must be supple when tanned, require not only to be freed from lime before going into tan, but also require a portion of the interfibrillar substance to be dissolved out, and the fibres brought into such a condition that the resultant leather will stretch without springing back. The removal of the lime, and perhaps also some of the interfibrillar substance, may be effected by means of acids used in a careful way, but as my object is to discuss the bacteriological problems of the bate, I shall pass over the purely chemical methods, and proceed directly to the fermentative processes which have been in use for this purpose since very early times. The skins are first washed to remove as much lime as possible, after which, hides for dressing or harness leather are passed through a bate, consisting of an infusion of pigeon or hen manure. Skins for light leathers, such as goat and sheep, are treated with an infusion of dog manure in water at a temperature of 30° to 40° C. This somewhat disgusting process under normal conditions produces excellent results, and the great difficulty in finding an efficient substitute has been to combine in one bath the peculiar effects of the dung bate. Since the cause of the action in the two bates is very similar, I shall refer more particularly to the dog dung bate, which is usually known as a puer. Skins in the bate lose their plumpness and firmness, and become soft and slippery, or "fall," as we term it. The bating liquor has some osmotic effect, which causes the swollen fibre to give up its water. This falling also mechanically squeezes out a further quantity of lime, and at the same time a considerable chemical action takes place, so that the skin which originally contained 5 per cent. of lime will, on coming from the puer, contain only 0·7 to 1 per cent. of lime, calculated on the dry weight of skin. What is it in the dung which produces this extraordinary result? So far as our present knowledge goes, the causes are very complicated: there is (1) the chemical action of various salts of organic acids which are contained in the dung. This is chiefly confined to the solution of lime, the reaction being similar to that taking place in a solution of ammonium chloride.

$$2NH_4Cl + Ca(OH)_2 = CaCl_2 + 2NH_3 + 2H_2O.$$

(2) The osmotic effect we have mentioned above; the interpretation of it is not yet quite clear, and I shall not therefore attempt to explain it.

(3) The action of bacteria and of enzymes produced by these organisms undoubtedly plays the greatest part in the "bringing down" of the skins, because, not only do they produce the acids, ammonia and amines which bring about the chemical reactions, but they also produce digestive ferments or enzymes, which have a solvent action on the fibres of the skin.

With the object of ascertaining the effect of the various species of bacteria contained in the dung upon skins, a large number of various species have been isolated, and the effect of pure cultures in different media has been tried.[1] A number of the results have been published in this Journal. Professor H. Becker, who has done a great deal of this part of the work, is of opinion that the principal organisms concerned in the bating exist in the dogs' intestines, and belong to the group of coli bacteria. These are very widely distributed bacteria, and are found in the large intestines and mammals, and, as a consequence, in almost all soils, and in the mud of rivers and lakes.

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[1] The subject is not so far removed from direct human interest as one might suppose. For many years Metschnikoff, in Paris, has been studying the bacterial flora of the human intestines. His theory is that old age is caused by the poisonous products of these intestinal bacteria, and he proposes to counteract the effects of these poisonous organisms by introducing into the system large quantities of lactic acid bacteria, either in the form of tabloids, or in the form of sour milk cultures.

Lortet found it along with other organisms in the mud of the Lake of Geneva at a spot where the water was chemically very pure. Dr. A. C. Houston, the bacteriologist of the Metropolitan Water Board, enumerates sixteen varieties of this organism, 80 per cent. of which produced acid and gas in lactose peptone cultures, indol in peptone water cultures, and when grown in milk produced acid and clot. The bacterium slide resembles that of typhoid fever, and has frequently been mistaken for it. It is, however, much more resistant to destructive influences. As you see, it is a short bacillus, possessing flagellæ by which it moves more or less rapidly.

Professor Becker's Bacterium No. 12, which he has named *Bacillus erodiens*, is undoubtedly a variety of *B. coli*, but has a more rapid motion, and does not coagulate milk, although it renders it somewhat thick. Cultivated in broth it gives off much gas, consisting of 12 per cent. carbon dioxide, 85 per cent. hydrogen, 3 per cent. oxygen. If glucose be added the quantity of carbon dioxide rises to 40 per cent. and acid is produced. The most rapid growth is at 37° C. and at this temperature a broth culture has a distinct reducing action on skin. According to the medium in which it is grown, it produces acid or alkali, and thus comes under the heading of mixed bacteria. In sugar[1] solutions acid is produced, and in proteid solutions ammonia compounds, indol and evil smelling gases are given off. Thus by varying the medium the effect produced may also be varied. I shall refer to this a little later.

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[1] Dr. A. C. Houston has been kind enough to make an examination of *B. erodiens*, and to ascertain its action on various sugars. It produces fluorescence in neutral red broth cultures, acid and gas in lactose cultures, indol, and acid and clot in milk cultures. It ferments dulcite with production of acid, but *not* cane sugar, adonite, inulin, inosite, salicin, or raffinose.

I found in studying the bacteria of dog dung that the species existing in the *fresh* dung, which developed in ordinary plate cultures, appeared to belong to four or five species only, mostly bacilli. At the end of two or three weeks, the original species had given place to others, mostly cocci, in a very similar way to the change which takes place in putrefaction. It will be seen, therefore, that no single species produces the complex chemical and physiological changes which take place, or the bodies necessary for the bating of skin as some observers have supposed, but the various species succeed one another as the medium changes its reaction and composition until finally the organic portion is resolved into the simplest bodies, such as carbon dioxide, ammonia and hydrogen. There is thus a moment when the dung is at its best so far as the bating action is concerned, and this moment is due to the vital activity of bacteria, and consequently varies according to the temperature, and some other influences (electrical condition of the atmosphere, etc.). One may say it is at its best at about fifteen days in summer, and one month or more in winter. Puer which has been dried is not so powerful in its action as that which is immediately made into a paste with water. It appears to lose its "nature," partly owing to irreversible dehydration processes and partly because some of the bacteria are killed. I have here plate cultures on agar from fresh puer, and from a puer wheel in use. These show the number of bacteria in the puer wheel to be much greater than in the fresh puer. Many of the species of bacteria resemble one another very closely, and to show every species would weary you to no useful purpose. I shall, therefore, only throw on the screen the principal species existing in puer.

It will be noted that many of these organisms are identical with those which carry on putrefaction. The quantity of ammonia and volatile bases produced is very small, but non-volatile bases are produced in considerable quantity; the problem of the constitution of these, and of their mode of action on skin, is one awaiting solution.

Another group of organisms which have some influence in the bating process are the class called by Beijerinck *Granulobacter.* They produce butyric acid, and this acid combining with the ammonia compounds of the dung forms salts which undoubtedly exert an effect on the lime in the skins, though its action on the fibre is not so great as the compounds of lactic and propionic acids.

I have pointed out previously the importance of the nutrient medium, or substratum, in which the bacteria grow, on the species surviving. In it one can see on a small scale the Darwinian process of natural selection. There is a great struggle for existence between the various species, and the circumstances determining the survival of this or that organism are extremely complicated, and we are yet very much in the dark as to the action of the various chemical compounds contained in the puer, so that it is unsafe to neglect even those which are present in only small amounts. Very minute quantities of certain bodies, almost too small for detection by chemical means, are sufficient to cause large differences in the growth of certain organisms. For instance, Raulin found that the addition of a trace of zinc to his nutrient liquids increased the crop of the mould *Aspergillus niger* more than four times the weight of a crop grown in the same liquid free from zinc.

If we inoculate a nutrient material with a pure culture of bacteria, and the medium is not exactly adjusted to the needs of the particular organism, it will not thrive, and will speedily be overgrown by some other species obtaining access from the air. This fact very much discounts the use of pure cultures of bacteria which have been proposed for bating, although in the case of Erodin, where the medium has been adjusted to suit the organism, considerable success has been attained. The whole of the enzymes and chemical compounds essential for a perfect bate, are not present in the dung when it leaves the animal's body, but these compounds are produced by the continued action of these and other bacteria which obtain access from the air. The production of the enzymes depends, too, upon the composition of the nutrient medium, since this exerts a selective influence on the species of bacteria obtaining access to it. Just as in the spontaneous souring of milk numerous bacteria have free access to it, yet the lactic ferment is generally so pure that it may be and is used as a pure culture on a large scale in the manufacture of lactic acid.

Seeing that the action of the dung varies in a great measure, according to the food on which the animals have been fed, and in the main a carnivorous diet is more effective than a vegetable diet, it was thought that the dung of an animal fed entirely on a meat diet would have a greater effect. I, therefore, procured some lion's dung, and puered skin with it, but it was found to have less action than the ordinary dog puer employed. The same result was obtained after keeping it for several weeks, and allowing the bacterial flora to develop.

The chemical composition of the lion's dung was as follows:—

Water	59·2 per cent.
Ash	21·1 ,,
Lime (CaO)	10·3 ,,
Phosphates (P_2O_5)	10·67 ,,
Organic matter	19·7 ,,

A bacteriological examination showed the presence of *B. coli* and a liquefying *diplococcus* not identified. A curious feature was a branching mould with extremely fine mycelium, in parts developing into yeast-like cells, and which invaded the whole plate.

The recent researches of Tissier and Metschnikoff have shown that the flora of the intestines, both of men and animals, consist very largely of anaerobic bacteria. These have been overlooked in previous researches, owing to imperfect means of studying this class of organisms. Indeed, in one work on the microbes of the alimentary canal of the dog no mention was made of them, whereas they are all very active.

The following anaerobic bacteria have been isolated:—*B. bifidus, B. perfringens, B. bifermentans, B. funduliformis* (Veillon), *B. capillosus, B. sporogenes, B. ventriosus, B. Rodella III, Staphylococcus parvulus, Diplococcus orbiculus, Coccobacillus preacutus, Coccobacillus oviformis.* Most of these organisms, and the new methods by which they have been isolated, are fully described in a new work entitled "Les Anaèrobies" by M. Jungano and A. Distaso, of the Pasteur Institute, Paris.

Various bates have been patented based on the above-mentioned researches,[1] and in a recent patent it has been proposed to use an extract of the pancreas in conjunction with an ammonium salt.[1] Undoubtedly this will have a certain bating action, as I showed as far back as 1894, but I do not think from the evidence we have at present that the action of living bacteria can be dispensed with. Enzymes are of a colloidal nature, and consequently will not penetrate a semi-permeable membrane-like skin, but the bacteria entering by means of the vessels and ducts into the interior of the skin produce their products *in situ*, and the action is thus greatly intensified.

Professor Procter, in his recent paper, to which I have referred above, says (page 331), "There is, however, no reason that all the necessary effects both of puering and bating should not ultimately be attained by purely chemical treatment without the risk and uncertainty which must always attach to bacterial and ferment action."

While I agree with him in this, still it is well to remember that in the case of one of the very oldest of the fermentation industries, that of the production of alcohol, a comparatively simple body, the natural process has not yet been replaced by a chemical one, and I believe this applies also to the manufacture of vinegar.

Chemical methods of bating may be used for leathers like chrome and alum leather, but even here natural processes like drenching, in which acids are produced gradually during the working of the skins, give more beautiful results. With vegetable tanning materials the advantage is still on the side of the natural processes when these are conducted in a proper manner.

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[1] "Oropon," an artificial bate, manufactured by Röhm & Haas of Darmstadt.

List of Bacteria which have been found in dung (mostly dog dung).

1. *Micrococcus ureae* (Cohn), (Pasteur).
2. „ *fulvus* (Cohn) (Crookshank, p. 221, Macé, and Zopf.).
3. „ *prodigiosus.*
4. „ *ureae liquefaciens.*
5. *Bacterium sulphureum.*
6. „ *coli commune.*
7. „ *coli anindolicum*
8. „ *coli anaerogenes.*
9. „ *furfuris* α.
10. „ *furfuris* β.
11. *Bacillus fluorescens putridus.*
12. „ „ *liquefaciens.*
13. „ *subtilis.*
14. „ *saprogenes* (Herfeld, this J., May, 1895) three varieties.
15. „ *butyricus* (Hueppe).
16. „ *putrificus-coli.*
17. „ *pyocyaneus.*
18. „ *janthinus.*
19. „ *coprogenes foetidus.*
20. „ *pyogenes foetidus* (a variety of *B. coli*).
21. „ *zenkeri.*
22. „ *magnus.*
23. „ *spinosus.*
24. „ *liquefaciens* (Eisenberg).
25. „ *amylobacter* (Van Tieghem).
26. „ *acidi paralactici.*
27. „ I. } Isolated from horse manure by Severin, Centr Bl. f. Bakt. (2), I., 97.
28. „ II.
29. „ III.
30. „ from horse dung (anaerobic) Severin, Central Bl. für Bakt. (2) III., 708.
31. „ from horse dung (anaerobic), No. 3.
32. „ *oedematis maligni* (Vibrion Septique, Pasteur).
33. „ *mesentericus vulgatus.*

34. *Bacillus lactis aerogenes.*
35. " *cavicida* (Brieger).
36. " *albuminis* (Bienstock).
37. " *Bienstockii.*
38. " *tenuis.*
39. " *enteritidis sporogenes* (Klein).
40. " *lactis acidi* (Ankerschmid, 1905).
41. " *megatherium* "
42. " *cadaveris sporogenes* (Klein) said to be identical with No. 16.
43. " *thermophilus* (Houston).
44. " *a.* from puer. Wood, p. 8. J.S.C.I. 1898, p. 1012.
45. " *b.* " " " " " "
47. " *mycoides.*
48—61. 14 species isolated from dog and pigeon dung by Prof. H. Becker. Zeit. f. Öffentlich. Chemie. Heft xxiii. Jahrgang X. p. 447.
62. *Sarcina fimentaria* (Lehmann and Neumann).
63. *Streptococcus* from Sewage. Houston, 7, pp. 104, 114.
64. " *brevis.*
65. " *longus.*
66. " *pyogenes.*
67. " *liquefaciens coli.* (Gamgee. Phys. Chem. 2).
68. *Streptothrix* from stable manure. Severin, 6.
69. *Spirillum serpens* (Kutscher).
70. " *tenue* "
71. " *undula* "
72. " *volutans* "
73. " from pig dung. Smith, Centr. Bl. f. Bakt., 16, (1), 124.
74—76. *Vibrio*, three species isolated by Kutscher.
77. *Clostridum butyricum* (Prazmowski) said to be identical with No. 25.
78. *Streptococcus faecalis.* Sidney Martin, 37 and 38. Ann. Rep. Loc. Gov. Board, 1907—9.

Drenching.—After bating, the skins go through a simpler fermentative process known as drenching. An infusion of bran is generally used at a temperature of 35° C., 5 to 10 grs. per litre, or half to one lb. per 10 gallons. The skins from the bate, after washing in water, are placed in this liquid. It ferments vigorously for 18 to 24 hours. A considerable quantity of gas is evolved, and weak organic acids are produced, which are absorbed by the skins, and swell them slightly. In a drench taken in actual work, but without skins, the acids produced per litre were :—

Lactic acid	0·7907
Acetic acid	0·2402
Formic acid	0·0306
Butyric acid	0·0134
Total acids	1·0749

The composition of the gases was:—

Carbon dioxide	25·2 %
Hydrogen	46·7 %
Nitrogen	26·0 %
Oxygen	2·1 %

A small quantity of trimethylamine was also found. The nature of this fermentation was very thoroughly investigated by the author and Dr. W. H. Willcox from 1892 to 1897, and was found to be due to the specific action of bacteria, which we have called *Bacillus furfuris.* There are two varieties of this organism, α and β, which are very similar in form, and differ only in the shape of the colonies when grown in glucose gelatine, and also that when grown together they produce more acid than when growing separately. They are sensitive to acids, which inhibit their growth, and when the acidity reaches N 50, their growth ceases, and being non-sporing organisms, they soon die. They are present in the puer used for bating the skins, and consequently there is no difficulty in starting a fermentation.

The mode of action of the drench on skins may be summed up as follows:—

1. The solution of the last traces of lime which has not been removed by the bate, by the organic acids produced by the fermentation, and the subsequent swelling action of these on the skin fibres. The acids also dissolve a small amount of skin substance.

2. Simultaneously with (1) the distention and floating of the skins by gases produced by the fermentation, so enabling them better to take up the acids.

3. The mechanical absorption of dirt by the particles of bran or flour in the drench.

I do not know of any further investigation of the drenching process since the above research was made, but in practice, meal is now frequently used instead of bran, and consequently a smaller quantity may be employed. The mechanical effect of meal in removing dirt is not so great as with bran, but where the adherence of the bran to the skin is objectionable, no doubt the use of meal is to be preferred.

With regard to the production of acids by bacteria, Jordan[1] points out that there is no fundamental difference between the formation of acid, and alkali by bacteria, since ammonia is just as much a true decomposition product of nitrogenous bodies, as are the amino acids which are produced by the digestion of gelatine, and in lactic acid and sugar fermentation. Both processes go on simultaneously, and the reaction of any culture medium, in which bacteria are growing, depends not only on the capability of these organisms of attacking certain substances or even on their chemical constitution, but also on the exact moment of growth when reaction is ascertained.

Bacteria of Tan Liquors.—We owe most of our knowledge of the fermentation processes going on in tan liquors to Professor F. Andreasch, of Vienna (born April 29th, 1867), who published the result of his work in "Der Gerber" in 1895–6. I had the privilege of knowing Andreasch personally, and can testify to the thoroughness with which his work was done. His death, June 14th, 1899, at Pörtschach in Carinthia was a great loss to the tanning world.

Andreasch found that neither yeasts nor bacteria ferment the tannin itself, but that they attack the non-tannins of the liquors with production of alcohol and acids. Some moulds, such as *Penicillium glaucum,* decompose the tannin, especially in those materials which contain only a small amount of non-tannin in comparison with their tannin, such as quebracho and knoppern.

It would be impossible in a short lecture to give details of Andreasch's work,[2] but the more important results of his researches may be briefly summarised thus:—

[1] Koch's Jahresbericht über Gährungsorganismen. 1906, p. 102.

[2] See abstract, *J.S.C.I.*, 1896, 910; 1897, 340, etc.

1. Putrefactive bacteria from the hides, bates, etc., accommodate themselves to the acid reaction of tan liquors; they dissolve certain nitrogenous constituents of the hide, and thereby furnish the chief nutriment for the more specific acid-producing bacteria. In liquors which are in use, the production of acid is proportional to the hide substance present, provided sufficient quantity of carbohydrates are present.

2. Acetic acid, which in fresh tan liquors is the chief acid, is always formed by two separate processes:—(1) the production of alcohol by yeasts from the glucoses of the non-tannins, and (2) the fermentation of the alcohol by acetic bacteria. In tan liquors it is never formed directly from carbohydrates.

3. Lactic acid is produced by several species of bacteria both from the sugars and other carbohydrates of tan liquors, and from the sugars alone by a yeast. A good supply of nitrogenous nutriment is necessary for its production, the greater part of which is furnished by the hides.

4. Butyric acid occurs in traces only in sound tan liquors.

A practical application of the results, is the preparation of sour liquors from materials poor in fermentable matter, by addition of glucose and alcoholic yeasts. A proper lactic fermentation is best induced by the sowing of the lactic yeast in the liquors.

I have given a list of the organisms isolated by Andreasch, which may be of use to workers on this subject.

Recently Von Schroeder (Zur Kenntnis des Gerbprozesses. Koll. Chem. Beihefte, Dresden, 1909, p. 21) found that, when a tannin solution was kept in contact with hide powder for 20 days gallic acid was formed, but that when the hide powder and the tannin solution were sterilised, no gallic acid was produced. He ascribes the formation of the gallic acid to the action of bacteria, but he makes no attempt to demonstrate their presence, although, in order to have the effect described by him, the microscopic demonstration of the bacteria should have been easy. It may be possible that there exists a specific organism capable of converting gallotannic acid into gallic acid.

LIST OF ORGANISMS TAKING PART IN THE FERMENTATION OF TAN LIQUORS. ANDREASCH.

A. *Yeasts.*
  1. *Saccharomyces pastorianus.* Hansen.
  2. *S. ellipsoideus.* Hansen.
  3. *S. apiculatus.* Reess.
  4. *S. ellipsoideus* I. Hansen.
  5. *S. acidi lactici.* Grotenfeld.
  6. A rose coloured *torula.*
  7. An orange-yellow *torula.*
  8. *Mycoderma.*

B. *Acetic acid ferments.*
  9. *Bacterium aceti.* Hansen.
  10. *B. Pasteurianum.* Hansen.

C. *Lactic acid ferments.*
  11. *Bacillus acidi lactici.* Hueppe.
  12. *Bacterium acidi lactici.* Grotenfeld.
  13. *Bacterium lactis acidi.* Marpmann.
  14. *Bacillus* XIX. Adametz.
  15. *Bacillus a.* Freudenreich.
  16. Lactic and *tyrothrix.* Duclaux.
  17. Lactic acid *bacterium* I. Andreasch.
  18. Lactic acid *bacterium* II. Andreasch.
  19. Lactic acid *Bacillus* α. Andreasch.
  20. Lactic acid *Bacillus* β. Andreasch.
  21. Lactic acid *micrococcus* α. Andreasch.
  22. *Bacterium acidi lactici.* Pasteur.
  23. *Bacillus lactis viscosus.* Adametz.
  24. Gas forming liquefying lactic acid bacillus. Andreasch.
  25, 26, 27. Lactic acid yeasts of tan liquors α, β and γ. Andreasch.

D. *Butyric acid ferments.*
  28. *Clostridium butyricum.* Prazmowski.

E. *Other organisms causing viscous or ropy fermentation.*
  29. *Bacillus viscosus.* Frankland.
  30. *B. mesentericus fuscus.* Hueppe.

Note.—*B. viscosus* is identical with *B. fluorescens liquefaciens.* Numerous other bacteria were found in the liquors but did not take part in the fermentation.

F. *Moulds.*
  31. *Penicillium glaucum*

Leather.—It is not possible to say much about the bacteriology of leather, and I do not know of any one who has worked at it. Many of the bacteria of the bates and tan liquors remain in the empty spaces of the leather from which the glands have been removed by scudding, etc., and Dr. G. Abt has been able, by suitable staining methods, to demonstrate these *in situ.* Figure 4, which has been prepared by Dr. G. Abt, of the Pasteur Institute, shows a section of calf skin tanned with shumac, and stained by Gram's method. The empty spaces of the skin contain a mycoderma and a few long bacilli. Owing to the great magnification necessary to show the organisms it is impossible to distinguish the tissue, although this is easily seen under the microscope. The illustration is interesting as being one of the first preparations of leather showing the presence of micro-organisms *in situ.* They are in all probability merely the dead organisms, and it is uncertain whether any are capable of further growth. I have not heard of any case of anthrax being conveyed by leather tanned from an infected hide, notwithstanding the very resistant nature of the spores of this organism.

Mycoderma vini and *M. cerevisiae* have also been found in the interstices of the leather. Every one knows that moulds grow very readily on damp leather, as may be seen in the case of a pair of boots left in a damp cupboard, and sometimes this is the case with leather in the drying rooms under certain conditions. The commonest variety met with is the green mould *Penicillium glaucum,* but there are cases in which *Aspergillus niger,* a black mould, has developed in spots during the drying of the leather, thus causing considerable damage.

I have also met with a case in which American shoulders stored by the Railway Co. had become damaged owing to a discoloration, caused by a mould. Other leather in the same store was not affected. It was found that the difference in behaviour was due to the presence of glucose and Epsom salts in the American leather, which, being hygroscopic, gave the moulds a very favourable nutrient medium. In some cases moulds grow upon coloured leather, and in so doing discharge the colour, causing light coloured spots. Quite recently Trotman (*J.S.C.I.*, 1909, 1238) has found a mould causing a pink coloration on skivers. He also found a variety of pink torula, which produced a brownish pink growth on the same goods.

An investigation of the various species of moulds growing upon leather would be very interesting.

It is impossible to give more than a general outline of a subject like this in one paper, and I must make this my apology for a very inadequate treatment of it.

In conclusion I should like to urge upon the Directors of the Leather Industries Department of the Leeds University, and of the new Technical College of the Leathersellers' Company, the necessity of taking up the bacteriology of leather manufacture in a manner worthy of the subject. It is impossible for this work to be taken up as part of a course by the present teachers. It requires continuous work in attending to the cultures, etc., and, therefore, requires a special room set apart for the work and a bacteriologist to give it attention. The work for such a man might well be combined with the microscopic study of skin and leather, the preparation and staining of sections of which demand a special technique, but which in my opinion is of equal importance with chemistry in helping us to understand what goes on in the process of making skins into leather.

I wish to acknowledge my indebtedness to Professor H. Becker, of Frankfort, for the loan of some of the slides, to Mr. A. Mee, of Nottingham, for the preparation of slides and diagrams, and to Dr. Gordon Parker for the loan of cultures.

PLATE 37.

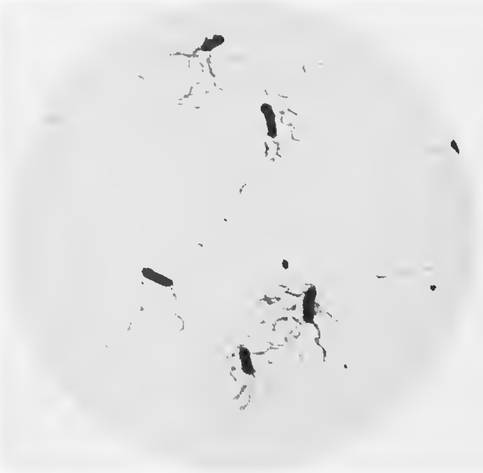

FIG. 1.
Bacillus putrificus (Bienstock). Photo by Prof. Kràl, of Prague.

FIG. 2.
Lime speck on a sheep skin.

PLATE 38.

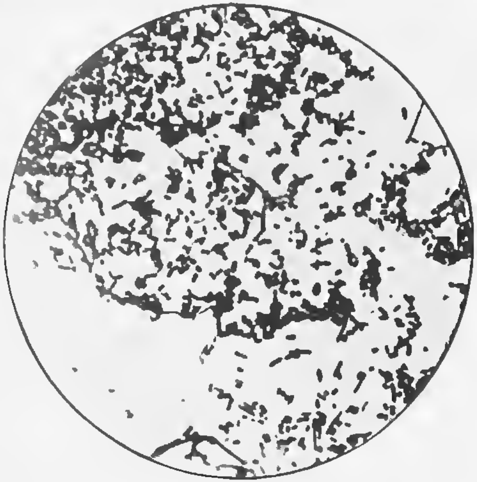

FIG. 3.

Pure culture of a bacillus (*d*) from the roots of wool from a "sweating" stove.

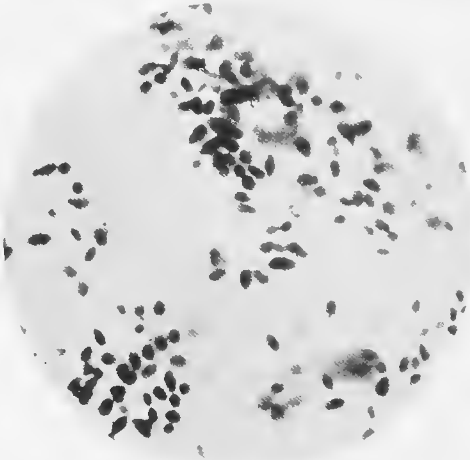

FIG. 4.

Section of sumac tanned calf skin, stained by Gram's method, and showing bacteria and mycoderma-like organisms *in situ*. The faint band across the picture is tissue. Preparations and photo by Dr. Georges Abt, of the Pasteur Institute, Paris.

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INDEX

Abomasum, 98
Abraham, 28, 29, 36
Abt, 226, 228
Acacia arabica, 348
Acari, 142
Acarina, 146
Acid, acetic, 230, 329, 352
— benzene-sulphonic, 352
— butyric, 230, 329, 352
— formic, 230, 267, 269, 284, 329, 347, 348, 352
— hydrochloric, 115, 329
— lactic, 230, 329, 352
— linoleic, 87
— linolenic, 87
— oleic, 87
— osmic, 213
— propionic, 352
— ricinoleic, 348
— sulphuric, 251, 252, 253, 329
— sulphurous, 230
Acland, 203
Actinomycosis, 152
Adipose tissue, 83, 84, 264
Allied Trades' Committee, 12
Ammonium chloride, 353
Andreis, 312
Antediluvian sheep, 22
Anthrax, 264, 266
Anthropology, 20
Areolar tissue, 78, 83, 84, 264, 282
Argali, 11, 52, 53
Armorica, 44
Artificial fattening, 77
— feeding, 11
— foodstuffs, 72
Arundel, Earl of, 227
Aspergillus niger, 254
Auricles, 109

Babul Pods, 348
Bacillus prodigiosus, 259
Bacon, 227, 228
Bane, 158
Becker, 229
Berry, 142, 143
Bile, 110, 115
Black mould, 254
Blood, 104
Bluebottles, 149
Board of Agriculture, 144
Bollinger, 152
Bos indicus, 60
Bran Drenching, 335
Breeds—
  Africander fat tailed, 58
  American wild, 52
  Ancient upland, 66
  Armenian, 54
  Australian, 63
  Bampton Nott, 66
  Barbary, 57
  Bharal, 56
  Blackfaced Heath, 66
  Cheviots, 66
  Cotswold, 69
  Cyprian, 54
  Devonshire South Harms, 69
  Dorset, 66
  Exmoor and Dartmoor, 66
  Hampshire Down, 66
  Herdwicks, 66
  Higher Mountain, 66

Breeds—*continued.*
  Kamschatkan wild, 52
  Karelin's, 54
  Kerry, 69
  Leicester, old and new, 69
  Lincoln, old and new, 66
  Long-wooled, 69
  Lonk, 66
  Mongolian Argali, 52
  Mouflon, 55
  New Oxford, 69
  New Zealand, 62
  North American, 64
  Old Berkshire, 66
  Old Hampshire, 66
  Old Norfolk, 66
  Old Radnor, 66
  Old Wiltshire, 66
  Orkney and Shetland, 66
  Ovis ammon, 52
  — *aries*, 57
  — — *steatopyga*, 60
  — *blandfordi*, 54
  — *canadensis*, 52
  — *gmelini*, 54
  — *hodgsoni*, 52
  — *jubata*, 53
  — *karelina*, 54
  — *musmon*, 55
  — *nahura*, 56
  — *nigrimontana*, 53
  — *nivicola*, 52
  — *ophion*, 54
  — *poli*, 53
  — *tragelaphus*, 57
  — *vignei*, 55
  Pamir wild, 53
  Patagonian, 60, 63
  Penistone, 66
  Portland, 66
  Radnor, 66
  Romney Marsh, 66
  Ryeland long-wooled, 66
  Sha, 55
  Shropshire, 66
  Soft-wooled, 66
  Somerset 66

Breeds—*continued.*
  South American, 64
  South Down, 66
  Spanish merino, 6
  Sussex, 66
  Teeswater, old and new, 66
  Tibetan Argali, 52
  Tierra del Fuego, 60
  Welsh, 66
  Wicklow, 69
  Wiltshire Down, 66
  Urial, 55
Brownian movement, 355
Burring, 270

CAIN AND ABEL, 22
Calcium formate, 329
— hydrate, 319
— hydroxide, 353, 355
— phosphate, 229
— sulphate, 229, 253
— sulphydrate, 233
Calliphora, 149
Capillary arteries, 109
— veins, 109
Cardium edule, 205
Carpenter, 150
Carthage, 41
Cartwright, 78
Castor oil seed, 348
Cercaria, 177, 179, 180, 181, 188, 194, 195, 201
Chyle, 109, 110, 115
Chyme, 98, 110, 115
Clyers, 151
Còathe, 158
Cockle, 13, 141, 204 *et seq.*
— fats, 87
Collagen, 353
Colloid, 300
Colon, 116
Colt in sheepskins, 87
Congo basin, 35
Coracles, 41
Crewels, 151
Crookshank, 152

Cross breeding, 11, 70
Crystalloid, 300
Cyst, 179, 180, 188, 194, 195, 201, 202

DAN, 160
Dantec, Le, 226
Darwin, 65, 75, 212
David, 33
Dead fat, 87
Dermatodectes ovis, 136
Digestive organs, 97
Dionysius Alexandrinus, 44
Diptera, 145
Distoma hepaticum, 159
Domestic sheep, 57
Dyeing, 27, 34

EDGAR, 48
Edward III., 47
Edward IV., 47
Epidermis, 109, 301
Esau, 33
Eugenists, 34
Evans, 40

FASCIOLA HEPATICA, 159
Fattening, 70
Fatty layer, 84, 280, 282, 302, 305, 306, 307, 308, 340, 346, 347
Fellmongering, 13, 14, 222 *et seq.*
Fly blow, 134, 147
Fluke, 124, 127, 156 *et seq*
Formic aldehyde, 270
Formic-mercury process, 266, 268
Fullers, 44

GAD, 29
Galaland, 36
Gastric Juices, 98, 125
Gazelle, 35
Geological scale, 21
Geology, 20
Gerlach, 187

Giddiness, 134
Glassy layer, 302
Gluten, 340, 341, 344
Goats, 35
Granulomata, 152
Greenbottles, 149
Green mould, 254
Guldberg, 332

HAGARITES, 29
Hamilco, 41, 42
Hatchett-Jackson, 203
Heath, 200
Hippocrates, 156
Historical references, 2
Hottentots, 35
Howell the Good, 135
Hyaline layer, 302
Hyksos, 36

IBEX, 35
Indian ox, 60
Indole, 116
Ixodes reduvius, 146

JOB, 29
Johnston, Sir H. H., 34, 35
Joseph, 36
Julius Cæsar, 36, 43

KATHREINER, 301
Keds, 142, 145
Keen, 335

LABAN AND JACOB, 23, 29, 30, 33
Lacteals, 109, 115
Lafar, 115
Lanoline fats, 87
Leather skin, 302, 305, 306, 307, 308, 309
Leuckart, 160
Lewis, 128

Lice, 142, 147
Limnœus pereger, 171, 182
Limnœus truncatulus, 169, 171, 172, 181, 182, 183, 184, 187, 189, 194, 197
Linolein, 214
Lipase, 347, 348
Liver, 110
Liver rot, 124, 157 *et seq.*, 308
Livy, 135
Lot, 29
Louping ill, 134
Lucilia, 149
Lucilia sericata, 149
Lucilium silverium, 151
Lydekker, 151

MACAULAY, 227
MacFadyean, 116
Maggots, 143
Malphigi, 213
Mammary glands, 126
Manaos, 260
Maniplus, 98
Marco Polo, 54
Maritime league, 44
Marseilles, 42
Mass Action, Law of, 332
Massilia, 42
Mazamet, 263, 274
Melophagus ovinis, 145
Mendl, 34
Mercuric chloride, 267, 268
Midian, 29
Milk from sheep, 25
Moab, 29
Moseley, 203
Moses, 34, 36
Muir, 72, 77
Muscidœ, 149
Musk ox, 49

NENCKI, 116
Neolithic man, 22
Nicholson, 212
North Wales, 39
Nucleus, 126
Nuttall, 116

ŒSOPHAGUS, 98, 103
Olein, 214
Omasum, 98
Oscillator drum, 345
Ovibos moschatus, 50
Ovid, 135

PALÆOLITHIC MAN, 21, 22
Palestine, 40
Palmer, 352
Palmitin, 214
Pancreas, 115, 347
Pancreatic juices, 88, 214, 215
Panniculus adiposus, 83, 280
Panniculus carnosus, 302, 305
Parasites, 125, 134
Parotid glands, 97
Payne, 281
Pech, 187
Pedesis, 355
Penicillium glaucum, 254
Pepsin, 115
Petrol ether, 347
Petrol ethyl ether, 216
Pharynx, 98
Phenol phthalein, 331
Philippo, 292, 293, 294, 295
Phœnicians, 25, 40, 41
Physiology, 69
Pinholes, 69,
Pliny (secundus), 28
Prehistoric sheep, 34
Priestman, 278
Procter, 19, 216, 221, 252, 253, 259 260, 261, 270, 301, 324, 353
Protoplasm, 126
Psoroptes communis, 136
Pulling down, 328
Pythias, 42

Rape grass, 209
Realgar, 319
Red arsenic, 319
Redi, 173
Redia, 173, 174, 175, 177, 181, 188, 194
Red muscle, 302
Rennet, 98
Rete malphigi, 302
Reticulum, 98
Reuben, 29
Rhinosceros, 21
Rhusma, 319
Richard, Cœur de Lion, 47
Rumen, 98, 103

Scab, 134
Schaefer, 78, 84, 88
Scudding, 334, 335
Sebaceous glands, 215, 334, 340
Semi-cholesterol-tallow fat, 215
Severtzeff, 54
Seymour-Jones, R.A., 19
Shakespeare, 159
Shatole, 116
Shearlings, 278
Sheep dips, 139
— maggot fly, 149
— scab, 134, 144
— shearing, 34
Sheepskin fats, 77
Shepherd kings, 36
Siberian plague, 265, 266
Sieber, 116
Simond, 159
Skin diseases, 12
Skin fat, 87
Sodium carbonate, 253
— hyposulphite, 254, 349
— silicate, 336
— sulphide, 233, 234, 278, 283, 284, 314
— sulphydrate, 233
Solomon, 25, 29, 33
South Kensington Natural History Museum, Director of, 19
Spooner, 97
Sporocyst, 172, 173, 174, 175, 177 187, 194
Staling, 272, 277, 291
Steapsin, 88, 214, 215, 347
Stearin, 214
Stephenson, 275
Stiasny, 216
Stockman, Sir S., 19
Stonehenge, 39
Stratum adiposum, 84
Striking, 148
Sturdy, 134
Sublingual glands, 97
Sulphuretted hydrogen, 116
Summaxillary glands, 97
Sweating, 272, 273, 274, 291

Tacitus, 43
Tallow fats, 87
Tar branding, 153
Tawing, 292
Thane, 78, 84, 88
Thierfelder, 116
Thomas, 19, 157
Thomson, 289
Ticks, 134, 143, 145, 146
Tin Isles, 41, 42
Tripe, 98
Trotman, 280, 281, 282
True skin, 302, 305, 307, 309
Trypsin, 215

Vascular system, 125
Veneti, 44
Virgil, 135
Von Recklinghausen, 104, 128

Waage, 332
Water-glass, 336

Weaving, 34
Wens, 151
Winchester, 44
Winter, 76
Wood, 226, 234, 251, 253, 254, 274, 276, 278, 280, 281, 282, 283, 288, 321, 338
Wool fat, 87
Wright, 226

YOUATT, 34, 75

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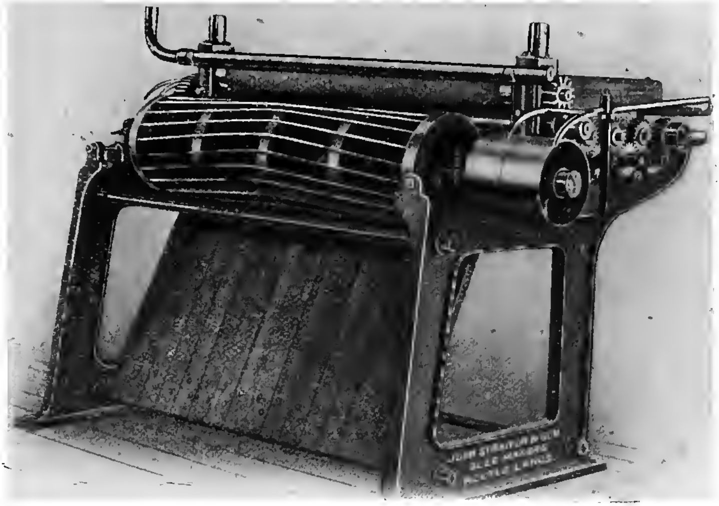

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